Little Blue River Watershed Diagnostic Study

SHELBY, RUSH, AND HENRY COUNTIES, INDIANA

April 5, 2004

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LITTLE BLUE RIVER WATERSHED DIAGNOSTIC STUDY
EXECUTIVE SUMMARY

The Little Blue River Diagnostic Study is a comprehensive examination of the Little Blue River and its surrounding watershed. In 2003, with funding from the Indiana Department of Natural Resources Lake and River Enhancement (LARE) Program, the Shelby County Soil and Water Conservation District hired the team of Indiana University and JFNew to conduct the study. The purpose of the study was to describe the historical and existing condition of the watershed, identify potential problems, and make prioritized recommendations addressing the issues documented throughout the study. The study included a review of historical studies, several mapping exercises, an aerial and windshield tour of the watershed, an assessment of chemical, biological, and physical stream health, and interviews with watershed residents and representatives from local and state agencies.

The Little Blue River Watershed encompasses 67,483 acres of Henry, Rush, and Shelby Counties from immediately south of Dunreith, Indiana southwest to the Little Blue River's confluence with the Big Blue River in Shelbyville. The watershed is 79% row crop agriculture. Conservation tillage is utilized on 78% of soybean fields and 37% of corn fields. The Little Blue River is considered warmwater habitat, while all tributary streams sampled are considered modified warmwater habitat due to structural modifications and their use as drainage ditches. The watershed houses five confined feeding operations containing a total of approximately 700 head of beef cattle and 7,600 head of hogs.

The study documented high levels of nitrate-nitrogen and *E. coli* in the watershed streams. The macroinvertebrate Index of Biotic Integrity (mIBI), an index which utilizes invertebrate community structure to measure water quality, documented a range of moderately impacted (2.5) to slightly impaired (7.25) macroinvertebrate communities. Habitat as assessed using the Qualitative Habitat Evaluation Index (QHEI) was also less than optimal for aquatic life uses at most sites. Water quality samples taken during storm events exceeded recommended concentrations for some chemical parameters and for *E. coli* at many sample sites.

Over 200 land treatment or restoration projects are recommended to reduce soil erosion and improve the biological, chemical, and physical condition of streams throughout the study area. Priority subwatersheds identified include the Rays Crossing, Little Gilson Creek, and Cotton Run Subwatersheds. Recommended land management treatments in the watershed include: livestock fencing, filter strip installation, wetland restoration, buffer zone establishment, bank stabilization, revegetation of exposed areas, and grassed waterway construction and maintenance. Nitrate-nitrogen and *E. coli* concentration reduction, nutrient and pesticide management, Conservation Reserve Program enrollment, coordination with the County Drainage Board, management at the watershed-level, and public education and outreach are also recommended.

ACKNOWLEDGEMENTS

This Watershed Study was performed with funding from the Indiana Department of Natural Resources Division of Soil Conservation and the Shelby and Rush County Soil and Water Conservation Districts. JFNew and Indiana University School of Public and Environmental Affairs documented the historical information available, completed tributary stream sampling for nutrient and sediment loading, and modeled nutrient and sediment loading to major rivers. Suzanne Lewis, Noell Krughoff, and Kerry Brown of the Shelby County SWCD and the Shelby County SWCD Board of Supervisors under the leadership of Brian Mohr and Steve Webb provided initiative and assistance in getting this study started and completed. Contributors to this study included: Linda Mahan of the Rush County Soil and Water Conservation District, Bill Harting of the Shelby County Natural Resources Conservation Service, Todd Davis, Stacey Sobat, and Chuck Bell with the Indiana Department of Environmental Management (IDEM); Mark Evans with the Purdue Cooperative Extension Agency; Jill Hoffmann, Jim Farr, Ron Hellmich, Brant Fisher, and Doug Keller with the Indiana Department of Natural Resources (IDNR); Scott Gabbard of the Shelby County Purdue Cooperative Extension Agency; Will Schakel of the Rush County Purdue Cooperative Extension Agency; William Pursley of the Shelby County Health Department; Ryan Cassidy of the Rush County Health Department; and Jan Hosier of Hoosier Riverwatch. Authors of this report included William Jones, Melissa Clark, Liz Zelasko, and Marisa Shetlarat of Indiana University and Sara Peel, Marianne Giolitto, Sara Slater-Atwater, and Joe Exl at JFNew. Sara Peel of JFNew provided GIS maps.

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1.0 <u>INTRODUCTION</u>

The Little Blue River Watershed is located northeast of Shelbyville and northwest of Rushville in Shelby, Rush, and Henry Counties, Indiana (Figure 1). The watershed drains approximately 67,483 acres (27,309 ha). The Little Blue River Watershed encompasses six 14-digit watersheds (Figure 2): the Little Blue River Headwaters Watershed (HUC 05120204030010), the Little Blue River-Gilson Creek Watershed (HUC 05120204030020), the Little Blue River-Farmers Stream Watershed (HUC 051202040030), the Beaver Meadow Creek-Linn Creek Watershed (HUC 05120204030040), the Little Blue River-Manilla Branch Watershed (HUC 051202040030050), and the Little Blue River-Rays Crossing Watershed (HUC 05120204030060). The study area lies within Addison, Marion, and Union Townships in Shelby County; Center, Jackson, Posey, and Walker Townships in Rush County; and Spiceland Township in Henry County. For the purpose of this study, the watershed was further divided into ten smaller subwatersheds. Three of the subwatersheds, the mainstem subwatersheds, contain a portion of the Little Blue River mainstem and two to three of the Little Blue River's major tributaries (Figure 3). The remaining seven subwatersheds correspond with the seven major tributaries (Figure 4).

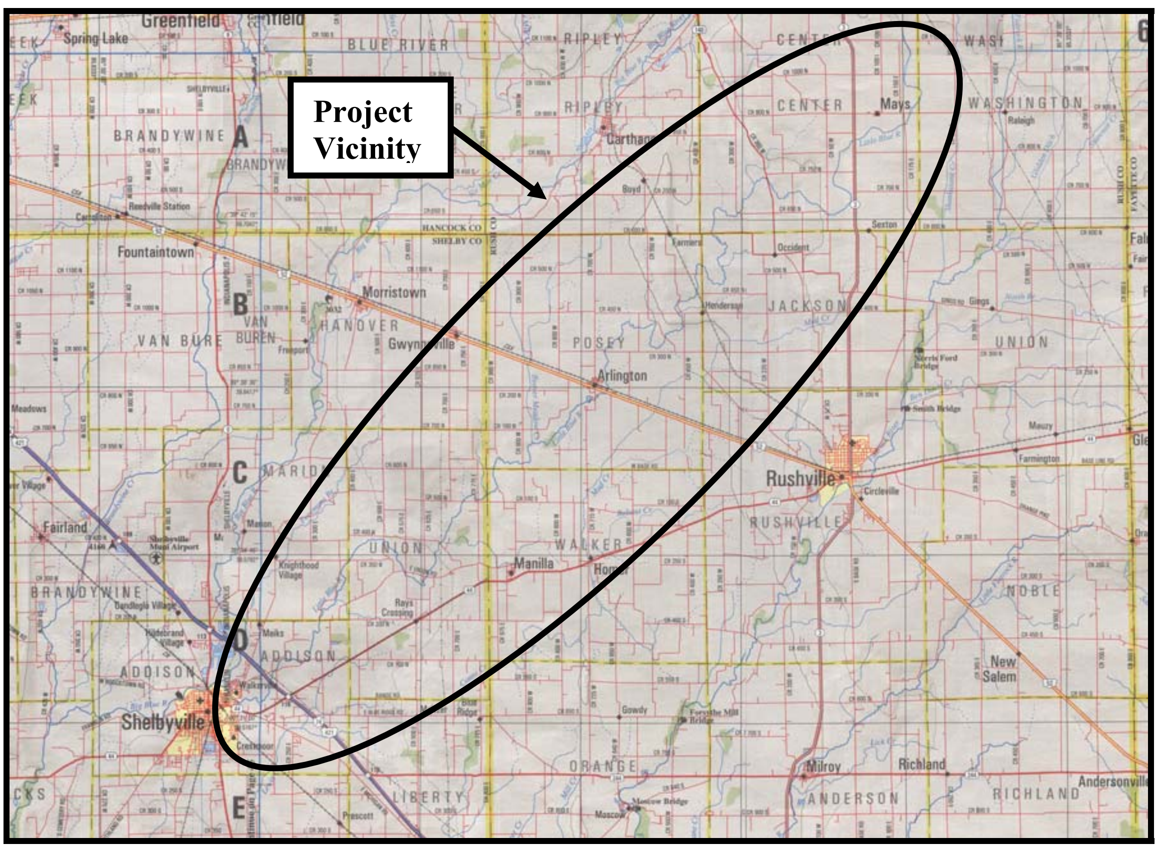


Figure 1. Study location map. Source: DeLorme, 1998.

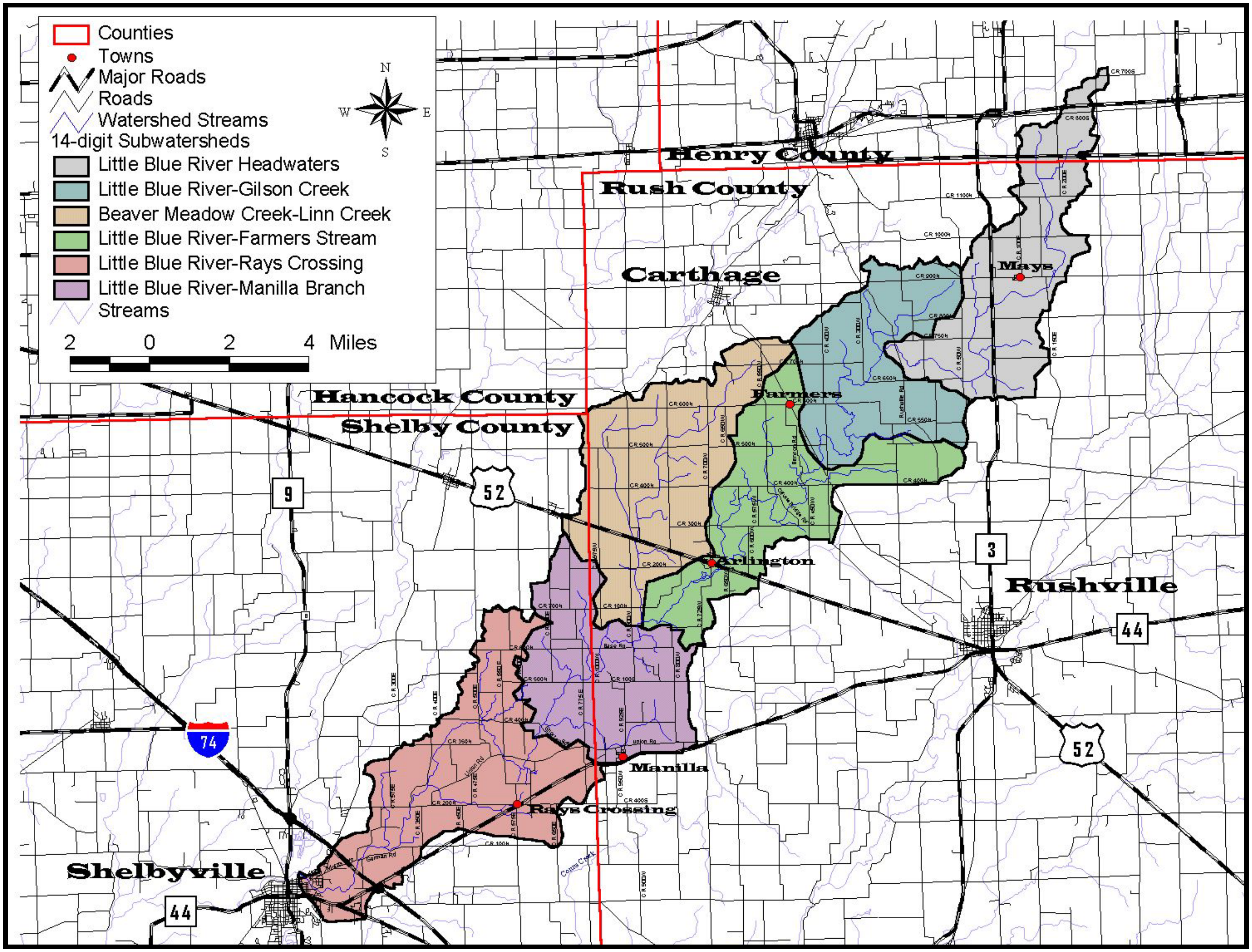


Figure 2. The six 14-digit watersheds that comprise the Little Blue River Watershed. Source: See Appendix A.

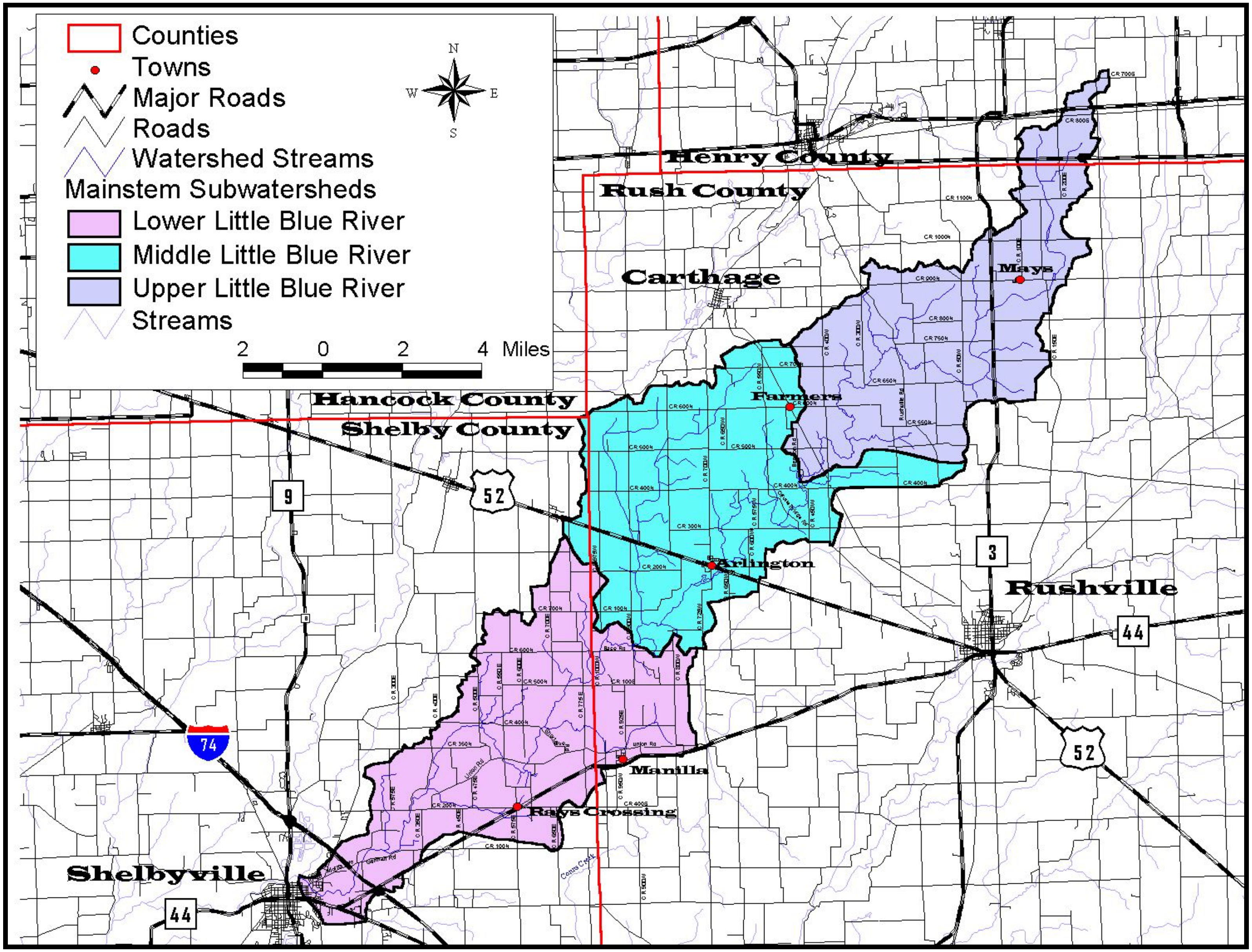


Figure 3. Mainstem subwatersheds. Source: See Appendix A.

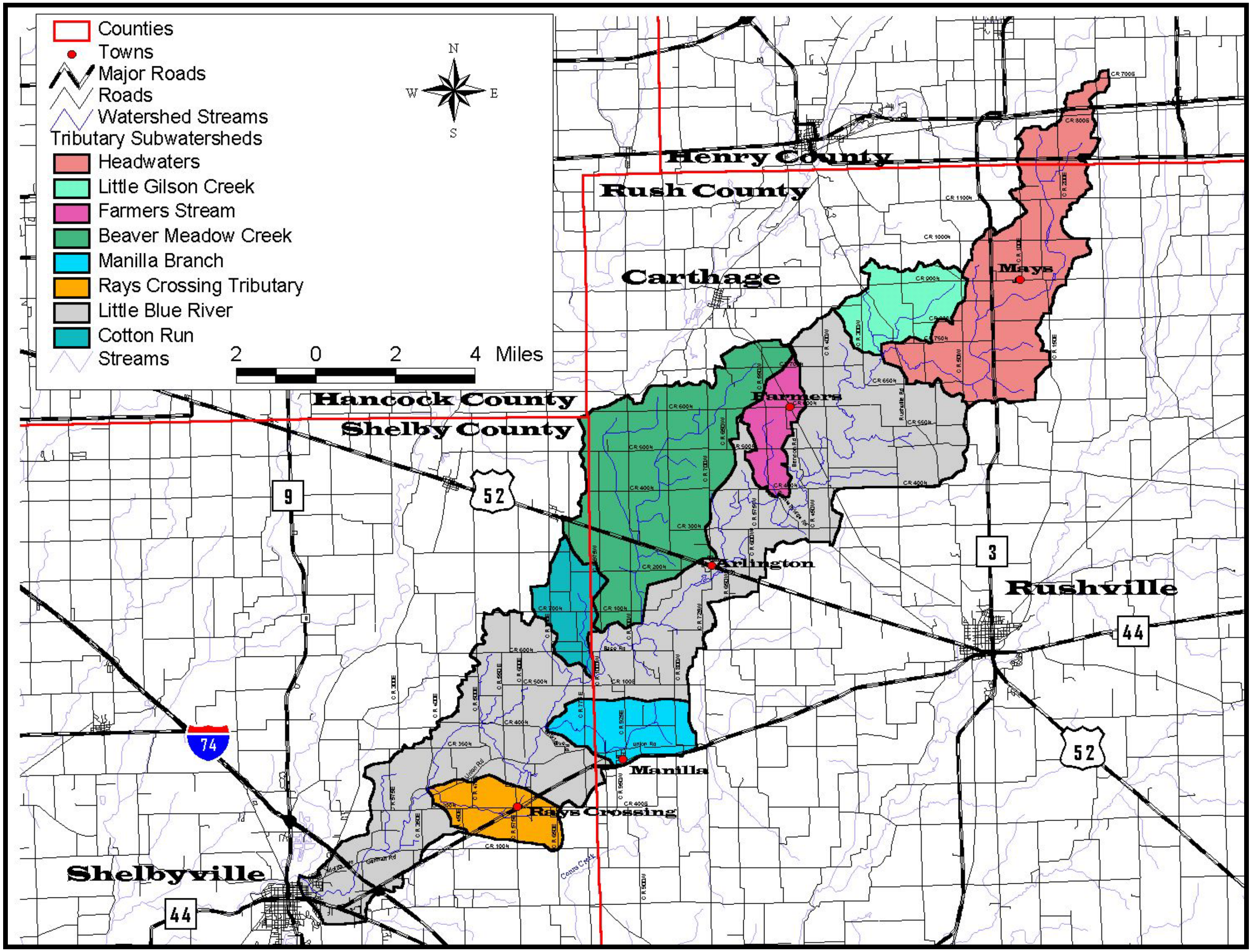


Figure 4. Tributary subwatersheds. Source: See Appendix A.

The Little Blue River Watershed is part of the 8-digit Driftwood River Watershed (HUC 05120204; Figure 5). Water from the Little Blue River discharges into the Big Blue River in Shelbyville, Indiana. The Big Blue River flows southwest where it joins Sugar Creek north of Edinburgh, Indiana and becomes the Driftwood River. The Driftwood River is a tributary of the White River, which converges with the Wabash River east of Mount Carmel, Illinois.

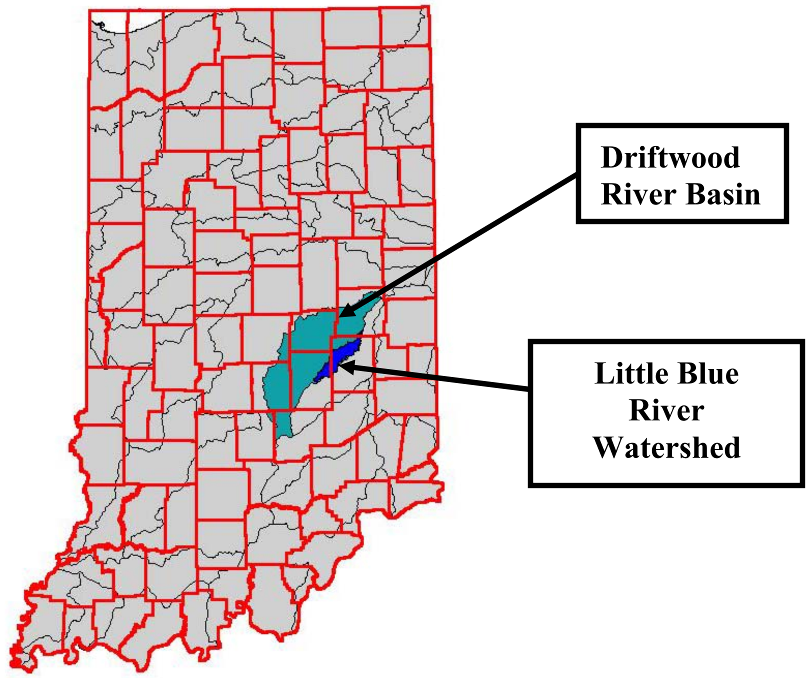


Figure 5. Driftwood River Basin. Source: See Appendix A.

It is important to note that many of the study streams are legal drains. Rays Crossing Tributary, Manilla Branch, Sulpher Run, Cotton Run, Beaver Meadow Creek and its tributaries, Henderson Ditch, Reddick Ditch and the Little Blue River from one mile west of State Road 3 to its headwaters in Henry County are all legal drains. Legal drains are necessary for water conveyance to sustain a variety of land uses, including agriculture. Disturbance to the legal drain system is inevitable due to periodic drainage improvement projects. These projects can negatively impact habitat, biota, and water quality downstream of the project site. Any water quality improvement projects recommended through this study that might be constructed within the drainage easement require County Drainage Board permission. Some projects may not be permitted if they impede drainage. Permits from the U.S. Army Corps of Engineers (ACOE), the Indiana Department of Environmental Management (IDEM), and the Indiana Department of Natural Resources (IDNR) may also be required depending on the type of project.

The drainage basin of the Little Blue River was formed during the most recent retreat of the Pleistocene or Quaternary Era. The advance and retreat of the Wisconsin glaciers and the deposits left by the glacial lobes shaped much of the landscape found in the northern two-thirds of Indiana (Wayne, 1966). The soils of the majority of the watershed formed in thin silt mantle and leached clay loam of the Miami-Crosby silt loams association (Ulrich, 1966). The weathered soils tend to be poorly drained or somewhat poorly drain and possess erosion issues. Nearer the confluence with the Big Blue River, Little Blue River Watershed soils developed in the Alluvial Terraces (Ulrich, 1966). These soils are found in flood plains of current streams and in former floodplains of glacial streams. The soils tend to form terraces ascending from the stream into the floodplain (Ulrich, 1966).

The study watershed is located in the Tipton Till Plain Section of the Central Till Plain Region (Homoya et al., 1985). The Central Till Plain Region is bordered by the Wabash River Valley to the north, the Crawfordsville and Shelbyville Moraines to the south, and the state line to the east. Prior to European settlement, expanses of forested land covered the topographically homogenous plain (Homoya et al., 1985). Only remnants of the beech-maple-oak forest typical of the Tipton Till Plain are known to exist today. Most of these exist as the northern flatwoods community, which is characterized by red maple, pin oak, bur oak, swamp white oak, Shumard's oak, American elm, and green ash and is typically associated with poorly drained soils in the region. In slightly better drained areas, beech, sugar maple, black maple, white oak, red oak, shagbark hickory, tulip poplar, red elm, basswood, and white ash predominate. Bogs, prairies, marshes, seep springs, and fens also occur in small numbers scattered throughout the Tipton Till Plain (Homoya et al., 1985).

Changes in land use have altered the watershed's natural landscape. Settlers to the region drained wet areas and cleared forests in order to farm soils rich in both nutrients and humic material (decaying organic matter). However, this layer of rich soil was thin in many places and years of crop removal and erosion depleted nutrient supplies. Around 1850, fertilization with potassium and phosphorus began. Fertilization had no effect on crop yield until 1940 when Dr. George Scarseth discovered that massive doses of nitrogen could significantly increase productivity. Technology and industry have increased and continue to increase farm production. Today, approximately 94% of the Little Blue River Watershed is utilized for agricultural purposes.

Installation of subsurface tile drain networks, excavation of drainage channels, and straightening of many of the smaller streams throughout the watershed has allowed for the conversion of forests and wetlands to agricultural land use. This has had a negative effect on water quality, resulting in off-site, downstream water flow and quality concerns. In a review of agricultural practices and their impacts on the natural structure and function of aquatic systems, Osmond and Gale (1995) concluded that effects other than water quality problems have emerged due to these changes. These effects include alterations in water quantity, habitat structure, and energy transfer within streams.

Few studies have been conducted to document water quality and health within the Little Blue River Watershed. However, the 2002 Indiana Department of Environmental Management 303(d) list prepared for the U.S. Environmental Protection Agency indicates non-support of recreational uses due to *E. coli* for the entire length of the Little Blue River and its tributaries. Evidently, human impacts the Little Blue River Watershed are having an adverse effect on water quality and beneficial uses.

In order to gain a better understanding of this watershed, the Shelby and Rush County Soil and Water Conservation Districts (SWCD) applied for and received funding through the Indiana Department of Natural Resources Lake and River Enhancement (LARE) Program to complete a watershed diagnostic study. The purpose of this study was to describe the conditions in the watershed, identify potential problems, and make prioritized recommendations addressing these problems. This study included a review of historical data and information; correspondence with landowners and state and local regulatory agencies; collection of stream water quality samples and benthic macroinvertebrates; stream habitat quality evaluation; and field investigations identifying land use patterns and locations for best management practice (BMP) installation. This report documents the results of the study.

2.0 STUDY SITE

2.1 WATERSHED PHYSICAL CHARACTERISTICS

Tables 1 and 2 and Figure 6 contain overview data for the watershed including subwatershed area and stream lengths for all named streams. Subwatershed boundaries were defined based on topography and the location of chemical, physical, and biological sampling sites for this study. It is often desirable to consider subwatersheds or subdrainages because: 1) human communities are organized within small areas (e.g. the towns of Arlington, Rays Crossing, Manilla, and Mays, and the city of Shelbyville); 2) the subdrainage scale allows for the identification of areas where specific management practices can be recommended and instituted; 3) large watershed units may be too expensive to restore, while treatment of small areas may provide measurable water quality improvement (O'Leary et al., 2001). Additionally, watershed division allows for prioritization of resources to land areas of greatest concern and where conservation practices may have the greatest benefit. The Little Blue River Watershed was divided into three main portions or mainstem subwatersheds. Each of the mainstem subwatersheds contains two or three of the major tributaries to the Little Blue River. The seven remaining subwatersheds, or tributary subwatersheds, correspond with each of these tributaries. Mainstem subwatersheds shown in Figure 3 and tributary subwatersheds in Figure 4 are based on drainage route information available when water sampling was conducted in 2003. Excavation of new ditches and filling of old ditches, since summer of 2003, may have altered watershed hydrology as presented in this report.

Table 1. Watershed area for the three study mainstem subwatersheds and seven tributary subwatersheds.

Subwatershed	Site Number*	Subwatershed Type	Subwatershed Area
Lower Little Blue River Subwatershed	1	mainstem	23,512 acres (9,515 hectares)
Rays Crossing Tributary Subwatershed	2	tributary	2,500 acres (1,012 hectares)
Manilla Branch Subwatershed	3	tributary	2,923 acres (1,183 hectares)
Cotton Run Subwatershed	4	tributary	2,206 acres (893 hectares)
Middle Little Blue River Subwatershed	5	mainstem	20,493 acres (8,293 hectares)
Beaver Meadow Creek Subwatershed	6	tributary	12,584 acres (5,093 hectares)
Farmers Stream Subwatershed	7	tributary	2,006 acres (812 hectares)
Upper Little Blue River Subwatershed	8	mainstem	23,478 acres (9,501 hectares)
Little Gilson Creek Subwatershed	9	tributary	3,164 acres (1,280 hectares)
Headwaters Subwatershed	10	tributary	10,891 acres (4,407 hectares)
Little Blue River Watershed			**67,483 acres (27,309 hectares)**

*Site number refers to the water quality monitoring station number.

Table 2. Stream length of all named streams in the Little Blue River Watershed.

Creek/Ditch	**Stream Length (miles)**	**Stream Length (kilometers)**
Little Blue River	43.0	69.2
Beaver Meadow Creek	8.7	14.0
Little Gilson Creek	5.0	8.1
Manilla Branch	4.7	7.5
Linn Creek	3.6	5.7
Rays Crossing Tributary	3.1	4.9
Henderson Ditch	2.9	4.7
Farmers Stream	2.5	4.0
Cotton Run	2.4	3.9
Newhouse Ditch	2.4	3.9
Walker Brook	2.1	3.3
Sulpher Run	1.5	2.3
Hill Brook	1.4	2.3
Well Run	1.4	2.2
Reddick Ditch	1.2	2.0
Arlington Run	1.1	1.8
Bea Run	1.1	1.7
Ditch Creek	0.9	1.5
Pump Run	0.9	1.4
Cap Run	0.8	1.4
Walker Ditch	0.8	1.3
Dill Ditch	0.8	1.3
Ball Run	0.5	0.8
Stanley Brook	0.4	0.6
Unnamed Tributaries	15.0	24.2
Total	**108.4**	**174.4**

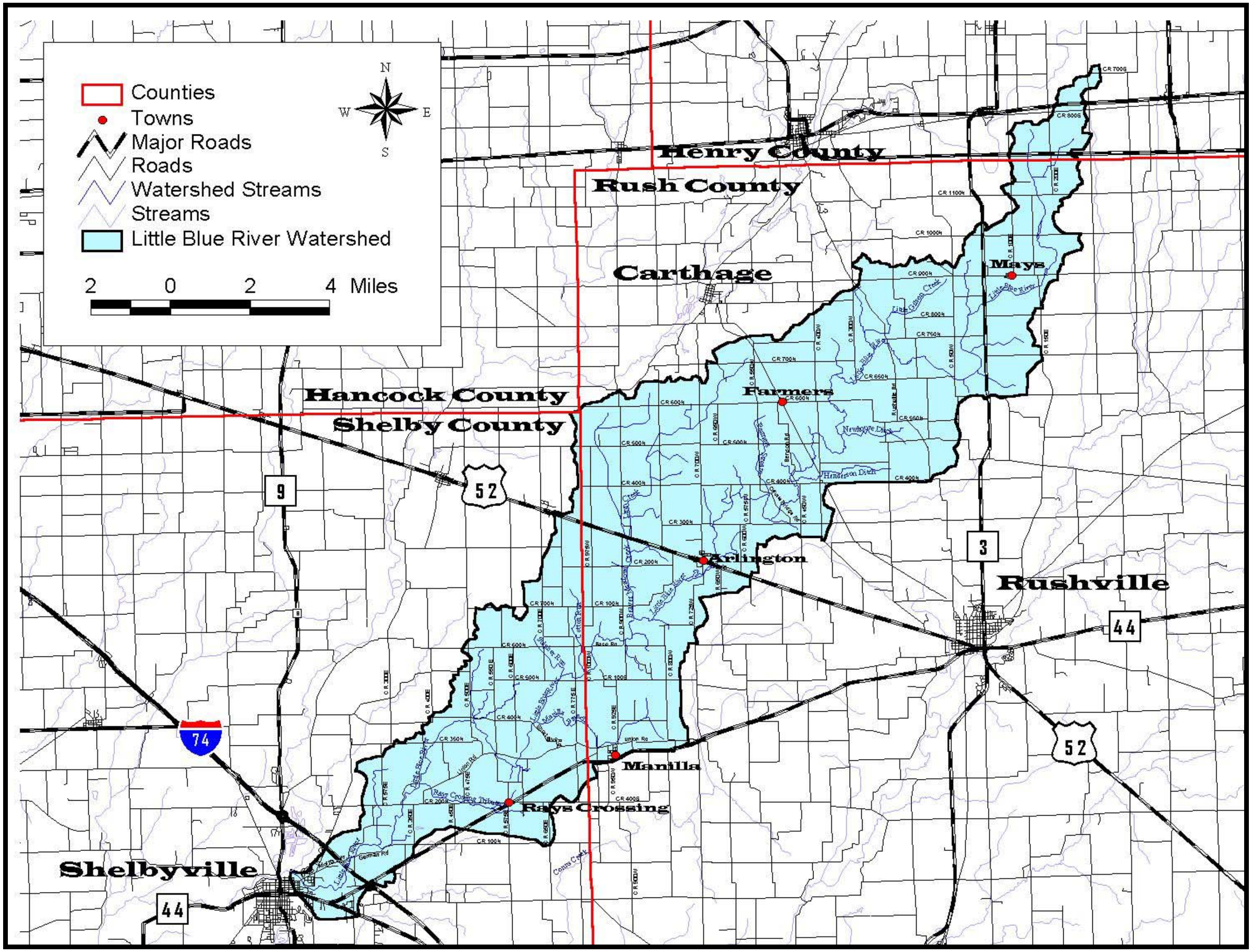


Figure 6. Waterbodies in the Little Blue River Watershed. Source: See Appendix A.

2.2 CLIMATE

Indiana's climate can be described as temperate with cold winters and warm summers. Climate can, however, differ from day to day as warm tropical air from the south or cool northern air interact or predominate, especially in the winter months. Due to this clash, low pressure systems are frequent and rainfall is generally abundant (National Climatic Data Center, 1976). Prevailing winds in Indiana are generally from the southwest but are more persistent and blow from a northerly direction during the winter months.

The climate of the Little Blue River Watershed is characterized as having four well-defined seasons of the year. Winter temperatures average 30ºF (-1.1ºC) while summers are warm, with temperatures averaging 85ºF (29.4ºC). The growing season typically begins in early April and ends in mid-October. Yearly annual rainfall averages 39.97 inches (101.5 cm). Winter snowfall averages of about 14 inches (35.56 cm). During summers, relative humidity varies from about 60 percent in mid-afternoon to near 90 percent at dawn. Prevailing winds typically blow from the southwest except during the winter when westerly and northwesterly winds predominate.

In 2002, almost 42 inches (107 cm) of precipitation (Table 3) was recorded at Morristown in Shelby County (Purdue Applied Meteorology Group, 2002). When compared to the 30-year average rainfall for the area, 2002 exceeded the average by over one and one-half inches. Year 2002 was characterized by significant wetter-than-normal and drier-than-normal periods. Winter (January and February) and summer (July and August) were uncharacteristically dry receiving approximately 5.25 inches (13.3 cm) less precipitation than is normal. Conversely, in April and May of 2002 Shelby County received 5.2 inches (13.2 cm) more rain than would have been received during a normal April and May. During 2003, rainfall was above normal with an unusually wet summer and fall. Shelby County received almost 46.5 inches (118.1 cm) of rain or nearly than 6.5 inches (16.5 cm) more rain than is average.

Table 3. Monthly rainfall data (in inches) for years 2002 and 2003 as compared to average monthly rainfall. All data was recorded at the Morristown gage station in Shelby County. Averages are 30-year normals based on available weather observations taken during the years of 1971-2000 at the Shelbyville Sewage Treatment Plant (Purdue Applied Meteorology Group, 2002).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
2002	1.45	1.92	4.35	6.48	7.12	3.61	2.60	1.04	4.61	3.28	2.39	2.95	41.80
2003	1.18	1.25	2.48	2.55	5.99	4.15	8.01	2.18	8.92	3.71	3.45	2.59	46.46
Average	**2.38**	**2.38**	**3.42**	**3.94**	**4.47**	**3.93**	**4.03**	**3.49**	**2.74**	**2.82**	**3.56**	**2.81**	**39.97**

2.3 GEOLOGY

The glacial topography of the Little Blue River Watershed is underlain by bedrock formed during the Ordovician, Silurian, and Devonian Ages about 40 million years ago. Limestone, shale, and dolomite of Silurian Age form both the headwaters and the lower portion of the Little Blue River Watershed. Devonian Age dolomite and limestone cover the central portion of the watershed through Rush County. A pocket of Ordovician shale and limestone runs parallel to the Little Blue River from Arlington to Shelbyville (Schneider and Gray, 1966). These bedrock formations characterize two bedrock groups: the Silurian Rocks Group present in the northern portion of the headwaters and the Muscatatuck Group which covers the remainder of the watershed from the headwaters to the Big Blue River confluence (Gray et al., 1987).

Topographically, the terrain slopes from eastern Rush County (900 feet msl) southward to Johnson County (100 feet msl). The bedrock surface generally follows the southwestward dip created by the axis of the Cincinnati Arch into the Illinois Basin at a rate of 10 to 30 feet per mile (Schnoebelen et al., 1999). The oldest rocks present in the area generally occur at the crest of the basin dipping to younger rocks near the edge of the Illinois Basin (Gutschick, 1966). This bedrock is now covered by unconsolidated surface deposits of sand, silt, gravel, and loam, which varies in thickness from less than two feet to twenty feet or more (Brownfield, 1991).

The advance and retreat of the glaciers in the last ice age shaped much of the landscape found in Indiana today. As the glaciers moved, they laid thick till material over the northern two thirds of the state. In the northern portion of the state, ground moraines, end moraines, lake plains, and outwash plains create a diverse landscape. A gently rolling glaciated plain crossed by end moraines covers the central portion of the state. End moraines, formed by the layering of till material when the rate of glacial retreat equals the rate of glacial advance, add moderate topographical relief to the landscape. Several poorly defined end moraines, including the Shelbyville and Knightstown Moraines, are scattered throughout the central portion of the state. The plain formed by glacial meltwater flowing from retreating glaciers deposited alluvial clay, sand, silt, and gravel. Stream channels are present where meltwater streams existed during the Wisconsin Age. Major rivers in central Indiana follow inherited channels formerly occupied by both proglacial (beyond the ice margin) and subglacial (underneath the ice) meltwater (Schneider and Gray, 1966).

In southeastern portion of central Indiana, the glaciers left two distinct physiographic zones: the Tipton Till Plain and the Muscatatuck Regional Slope (Malott, 1922). The Little Blue River Watershed lies within the Tipton Till Plain, which is bounded on the south by the Muscatatuck Regional Slope. The Tipton Till Plain is a nearly flat to gently rolling glaciated plain. The monotony of the plain is broken by eskers and esker troughs developed by stalled glaciers and meltwater drainageways, kames, and outwash plains left by active glaciers (Wayne, 1966; Schneider, 1966). The Little Blue River flows from northeast to southwest through the Tipton Till Plain following one of the former glacial meltwater channels (Schneider and Gray, 1966). The Muscatatuck Regional Slope formed by the southern boundary of glaciation in Indiana parallels the southern boundary of the Little Blue River Watershed.

The flow of the Little Blue River from northeast to southwest parallels glacial deposits, or moraines, from the advance and retreat of Wisconsin Age glaciers. The Shelbyville Moraine forms the southern boundary of the Little Blue River Watershed, while the Knightstown Moraine forms the northern boundary (Figure 7). The Shelbyville Moraine roughly marks the terminal position of the East White Sublobe of the Ontario-Erie Lobe of the first Wisconsin glacier and the southern boundary of glaciation in Indiana (Schneider, 1966). The Ontario-Erie Lobe flowed from north to south while the East White Sublobe flowed southeast. Together they carved out the eastern portion of the Tipton Till Plain across central Indiana. Wind deposition of a thin layer of proglacial silt on the soil surface and subsequent burial of the silt and loess under ice sheets created the Center Grove till of the Shelbyville Moraine (Schneider and Gray, 1966). Where the

Shelbyville Moraine exists today, the East White Sublobe stalled depositing an arc-shaped band of till. This arc-shaped band marks the southern boundary of the Little Blue River Watershed and the Tipton Till Plain. While the Ontario-Erie Lobe was stalled, wind deposited silt and loess atop the ice sheet. A second advance of the East White Sublobe, nearly 1000 years later, buried the silt-covered Center Grove till depositing silt and Cartersburg till; the Center Grove till-silt-Cartersburg till sandwich created the Trafalger Formation (Schneider and Gray, 1966; Wayne, 1966). The Trafalgar Formation can be characterized as a gently sloped plain with a variety of unconsolidated, Wisconsin Age deposits including dune sand, lacustrine sediments, outwash plain sediments, and till (Wayne, 1966; Homoya et al., 1985). Trafalgar tills are mostly composed of bedrock from Canada where the glaciers originated. A later Wisconsin Age glacial advance and retreat deposited the Knightstown Moraine, which forms the northern boundary of the Little Blue River Watershed.

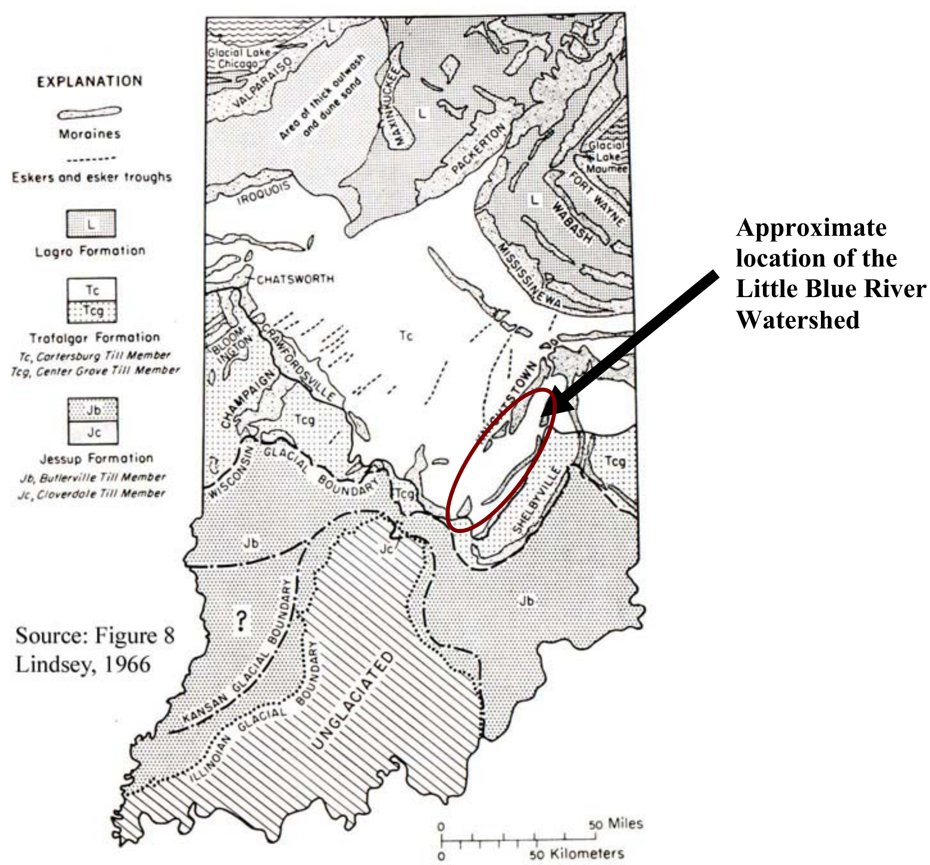


Figure 7. Moraine deposits in northern Indiana from the Wisconsin Glacial Period. Tc indicates areas of the Trafalgar formation, while L is the Lagro formation. Source: Figure 8 from Lindsey, 1966.

Three types of unconsolidated deposits were created during the Wisconsin Age north of the Shelbyville Moraine and south of the Knightstown Moraine, which form the Little Blue River Watershed. The Atherton Formation (outwash facies) forms the headwaters of the Little Blue River; the Martinsville Formation follows the main channel and floodplain of the river; and the Trafalgar Formation covers the Little Blue River Watershed from near its headwaters to its confluence with the Big Blue River in Shelbyville (Schneider and Gray, 1966). The Atherton

Formation consists of outwash-plain and valley-train sediments deposited by glacial meltwater. The Atherton Formation generally occurs along drainageways in association with the Martinsville Formation. The Atherton Formation contains the parent material for soils developing from strong calcareous gravel and sand such as the Fox, Homer, and Ninevah associations and soils developing from leached sand and silt with small amounts of sand and gravel like the Martinsville and Whitaker associations (Schneider and Gray, 1966). Formed after the retreat of the glaciers, the Martinsville Formation is the youngest unconsolidated unit recognized in Indiana. It is generally found as alluvial deposits along channels and in floodplains and is considered transient due to frequent scour and downstream deposition. The Martinsville Formation contains parent material for soils formed in neutral to alkaline alluvium such as the Genessee, Ross, Shoals, and Eel associations. The Trafalgar Formation is the most widespread unconsolidated deposit in Indiana. It can be divided into two principle units, the Cartersburg Till Member above and the Center Grove Till Member below. Generally, the Center Grove Member is identified by its greater quantity of wood fragments. Soils developed from the Center Grove Member are generally non-calcareous such as Fincastle, Russell, and Brookston, while Cartersburg Member soils are poorly drained, non-calcareous soils including Miami, Crosby, and Brookston.

2.4 SOILS

2.4.1 <u>Introduction</u>

The soil types found in the Little Blue River Watershed within Henry, Rush, and Shelby Counties are a product of the original material deposited by the glaciers that covered the area 12,000 to 15,000 years ago. The main parent materials found in the counties are glacial outwash and till, ice-contact sand and gravel deposits, alluvium, and organic materials that were left as the glaciers receded. The interaction of these parent materials with the physical, chemical, and biological variables found in the area (climate, plant, and animal life), time, and the physical and mineralogical composition of the parent material formed the soils located in the three counties today.

Surficial Ontario-Erie Lobe deposits are characteristically outwash sand and gravel within the Trafalgar Formation, the somewhat diffuse morainal structure drained by the watershed. Due to the variable and unconsolidated nature of the Wisconsin Age glacial deposits, eight different soil associations cover the study area (Brock, 1986; Hillis and Neely, 1987; Brownfield, 1991). Table 4 contains information on these general soil associations and where they may be found within the general topography of the watershed.

Table 4. Characteristics of general soil associations found within the study watershed.

County	Association	Description	Texture	Formation Process	Location
Henry	Crosby-Cyclone-Miamian	silt loam, silty clay loam, clay loam, clay	medium to moderately fine	in loess and the underlying glacial till	on glacial till plains and outwash moraines
Rush	Crosby-Treaty	silt loam, silty clay loam, clay loam, loam	medium to coarse	in loess and the underlying glacial till	on glacial till plains
Rush	Ockley-Westland-Sleeth	silt loam, clay loam, sandy clay loam, sand, gravel	fine to coarse	in glacial outwash	on glacial terraces and outwash plains
Rush	Genessee-Sloan-Shoals	loam, silt loam	medium	in alluvial deposits	bottom land
Rush	Miamian	silt loam, clay, clay loam	fine to medium	in loess and the underlying glacial till	on glacial till plains
Shelby	Genessee-Ross-Shoals	loam, sandy loam, silt loam	medium	in alluvium washed from areas of calcareous glacial till	on flood plains adjacent to major streams and their tributaries; in old stream meanders
Shelby	Miami-Crosby-Hennepin	silt loam, clay loam, loam	medium	in thin loess and glacial drift	on knolls, ridges, and breaks; on uplands
Shelby	Crosby-Brookston	silt loam, silty clay loam	fine to medium	in thin loess and glacial drift	on depressional areas, swales, and narrow drainageways; on uplands

Source: Brock, 1986; Hillis and Neely, 1987; Brownfield, 1991.

2.4.2 Highly Erodible Soils

Soils in the watershed and their ability to erode or sustain certain land use practices, can impact the water quality of the river systems in the watershed. For example, highly erodible soils are, as their name implies, easily erodible. Soils that erode from the landscape are transported to waterways where they degrade water quality, interfere with recreational uses, and impair aquatic habitat and health. In addition, such soils carry attached nutrients, which further impair water quality by increasing production of plant and algae growth. Soil-associated chemicals like some herbicides and pesticides can kill aquatic life and damage water quality.

Table 5 lists the soil units considered highly erodible by the Natural Resources Conservation Service (NRCS). It is important to note that highly erodible soil designations are based on countywide soil surveys; the soils at various locations have not necessarily been field-checked. Shelby County lists 19 highly erodible soils, while Rush County lists 5 highly erodible soils and Henry County lists 11 highly erodible soils. The county lists or the one provided in Table 5 can be cross referenced with the county soil survey to locate highly erodible soils on the landscape.

Table 5. Soil units within Henry, Rush, and Shelby Counties considered highly erodible by the local NRCS offices.

County	Soil Unit	Soil Name	Soil Description
Henry	EdD2-EdE2	Eldean silt loam	12 to 35 percent slopes, eroded
Henry	ExD3	Eldean clay loam	12 to 18 percent slopes, severely eroded
Henry	LeD2-LeE2	Losantville silt loam	12 to 30 percent slopes, eroded
Henry	LhC2-LhD3	Losantville clay loam	6 to 18 percent slopes, severely eroded
Henry	LsD2-LsE2	Losantville silt loam, stony subsoil	6 to 18 percent slopes, eroded
Henry	LxC3-LxD3	Losantville clay loam, stony subsoil	6 to 18 percent slopes, severely eroded
Rush	ElC3-ElD3	Eldean clay loam	6 to 18 percent slopes, severely eroded
Rush	MmD-MmE	Miami silt loam	12 to 35 percent slopes
Rush	MoC3-MoD3	Miami clay loam	6 to 18 percent slopes, severely eroded
Rush	MpD-MpE	Miamian silt loam	12 to 35 percent slopes
Rush	MuD3	Miamian clay loam	12 to 18 percent slopes, severely eroded
Shelby	CoE	Corydon stony silt loam	18 to 35 percent slopes
Shelby	CrB	Crosby silt loam	2 to 4 percent slopes
Shelby	FoC2-FoD2	Fox loam	6 to 18 percent slopes, eroded
Shelby	FxB3-FxC3	Fox clay loam	2 to 12 percent slopes, severely eroded
Shelby	HeE-HeF	Hennepin loam	18 to 50 percent slopes
Shelby	M1B2-MlD2	Miami silt loam	2 to 18 percent slopes, eroded
Shelby	MmB3-MmD3	Miami clay loam	2 to 18 percent slopes, severely eroded
Shelby	NeD2	Negley loam	12 to 18 percent slopes, eroded
Shelby	NeE	Negley loam	18 to 25 percent slopes
Shelby	PaC2	Parke silt loam	6 to 12 percent slopes, eroded
Shelby	PrC	Princeton fine sandy loam	6 to 12 percent slopes
Shelby	RoE	Rodman gravelly loam	18 to 35 percent slopes

Source: 1987 USDA/SCS Indiana Technical Guide Section II-C for Henry County; 1987 USDA/SCS Indiana Technical Guide Section II-C for Rush County; 1987 USDA/SCS Indiana Technical Guide Section II-C for Shelby County.

Highly erodible soil types have specific limitations in supporting certain classes of land use. Corydon stony silt loam (CoE), Eldean silt loam (EdC2-EdD2), and Eldean clay loam (ElC3-ElD3; ExD3) soils are erosion prone and due to steep slopes, moderate soil permeability, low available soil moisture capacity, rapid runoff, and droughtiness, building stability and agricultural productivity in these soils are limited. Installing grade stabilization structures, water diversions, or grassed waterways, and maintaining cover crops or using conservation tillage helps prevent soil loss. Rodman gravelly loam (RoE) soils are also limited by droughtiness making them suitable for pasture or woodland usage only. Excessive wetness and extreme erosion hazard limit the usage of Crosby silt loam (CrB) soils. Erosion is also the primary risk associated with Fox loams (FoC2-FoD2) and Fox clay loams (FxB3-FxC3). Due to moderate to very rapid soil permeability and low soil moisture capacity, runoff occurs rapidly on these soils. Although little steeply sloped Hennepin loam (HeE, HeF) and Losantville silt (LeD2-LeE2; LsD2-LsE2) and clay loam (LhC3-LsD3; LxC3-LxD3) soils exist within the watershed, these soils are particularly vulnerable to erosion. These soils are highly susceptible to runoff and erosion if the cover vegetation is removed.

Erosion, soil clump or clod formation, and organic matter depletion are risks associated with the remaining soils listed in Table 5. Miami (M1B2-MlD2, MpD-MpE), Parke (PaC2), and Miamian (MpD-MpE) silt loams, Negley loam (NeD2, NeE), Miamian clay loam (MuD3), and Princeton fine sandy loam (PrC) soils are suited to cultivation as long as erosion is controlled with BMPs and soil organic matter is maintained. However, Miami clay loam (MmB3-MmD3, MoC3-MoD3) soils are not suited for row crop cultivation under most circumstances. Overgrazing of these soils can cause surface compaction, excess runoff, or poor soil tilth.

Although highly erodible soils are located throughout the watershed, seven of these soils are of special concern. Miamian silt loam (MpE) and Miamian clay loam (MuD3) soils in Rush County and Crosby silt loam (CrB), Miami silt loam (MlB2), Miami clay loam (MmD3), Fox clay loam (FxC3), and Hennepin loam (HeF) soils in Shelby County directly border the Little Blue River. Special care should be taken at locations where highly erodible soils directly border the Little Blue River or its tributaries; cover crops should be maintained at all times at these locations.

2.4.3 Highly Erodible Land

Highly Erodible Land (HEL) is a designation used by the Farm Service Agency (FSA). For a field or tract of land to be labeled HEL by the FSA, at least one-third of the parcel must be situated in highly erodible soils and the tract of land must be used for agricultural production. Unlike the soil survey, these fields must be field checked to ensure the accuracy of the mapped soils types. Owners of farm fields mapped as HEL are required to file a conservation plan with the FSA in order to maintain eligibility for any financial assistance from the USDA. Figure 8 shows the location of HEL fields in the study watershed. Approximately, 2,268 acres (918 ha) of HEL exist within boundaries of the study watershed. This is about 3.5% of the Little Blue River Watershed. It is important to note here that the FSA only tracks HEL if the tract of land is used to produce crops. Parcels of land may be highly erodible but are not recorded as such if it is not used for production. Therefore, the 3.5% estimated may be an underestimate of the actual amount of highly erodible acreage in the watersheds.

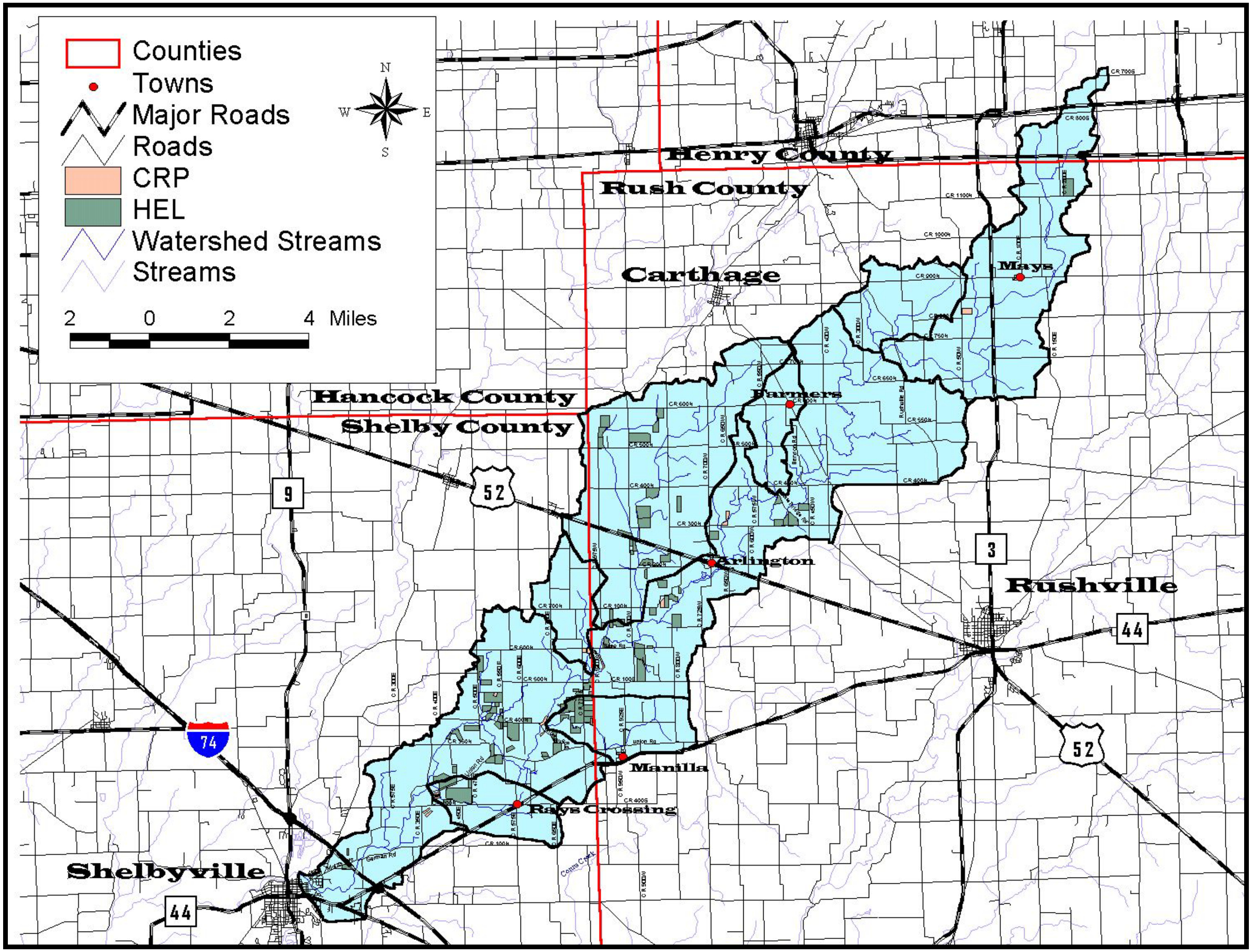


Figure 8. Tracts mapped as Highly Erodible Land in the Little Blue River Watershed. Source: See Appendix A.

Table 6 breaks the information down by subwatershed. Of the tributary subwatersheds, the Beaver Meadow Creek Subwatershed contains the most HEL acreage, 485.2 acres (196.4 ha). The Lower Little Blue River Subwatershed contains the most acreage mapped as HEL (1,382.5 acres or 559.5 ha) for the mainstem subwatersheds. The Rays Crossing Tributary and Manilla Branch Subwatersheds contain the highest percentages of HEL, 9.7 and 9.7%, respectively. All of the Little Blue River tributary subwatersheds, except the Farmers Stream and Little Gilson Creek Subwatersheds, contain some acreage of HEL. Generally, more HEL acreage is located in Shelby County and the western portion of Rush County.

Table 6. Area mapped in highly erodible map units by subwatershed and percent of each subwatershed that is considered highly erodible.

Subwatershed	Subwatershed Type	Acres	Hectares	Percent of Subwatershed
Lower Little Blue Subwatershed	mainstem	1,382.5	559.5	5.9%
Rays Crossing Subwatershed	tributary	242.6	98.2	9.7%
Manilla Branch Subwatershed	tributary	282.6	114.4	9.7%
Cotton Run Subwatershed	tributary	23.3	9.4	1.1%
Middle Little Blue Subwatershed	mainstem	789.5	319.5	3.8%
Beaver Meadow Creek Subwatershed	tributary	485.2	196.4	3.9%
Farmers Stream Subwatershed	tributary	0.0	0.0	0.0%
Upper Little Blue Subwatershed	mainstem	95.9	38.8	0.4%
Little Gilson Creek Subwatershed	tributary	0.0	0.0	0.0%
Headwaters Subwatershed	tributary	95.9	38.8	0.9%
Total		**2,267.9**	**917.8**	**3.4%**

Source: Farm Services Agencies of Henry, Rush, and Shelby Counties.

Figure 9 demonstrates that in general HEL is concentrated lower in the watershed. Most highly erodible lands within the Little Blue River Watershed occur where the slopes are steeper causing greater erosion potential. The upper portion of the watershed including the Little Gilson and Headwaters Subwatersheds are very flat and contain very little HEL area.

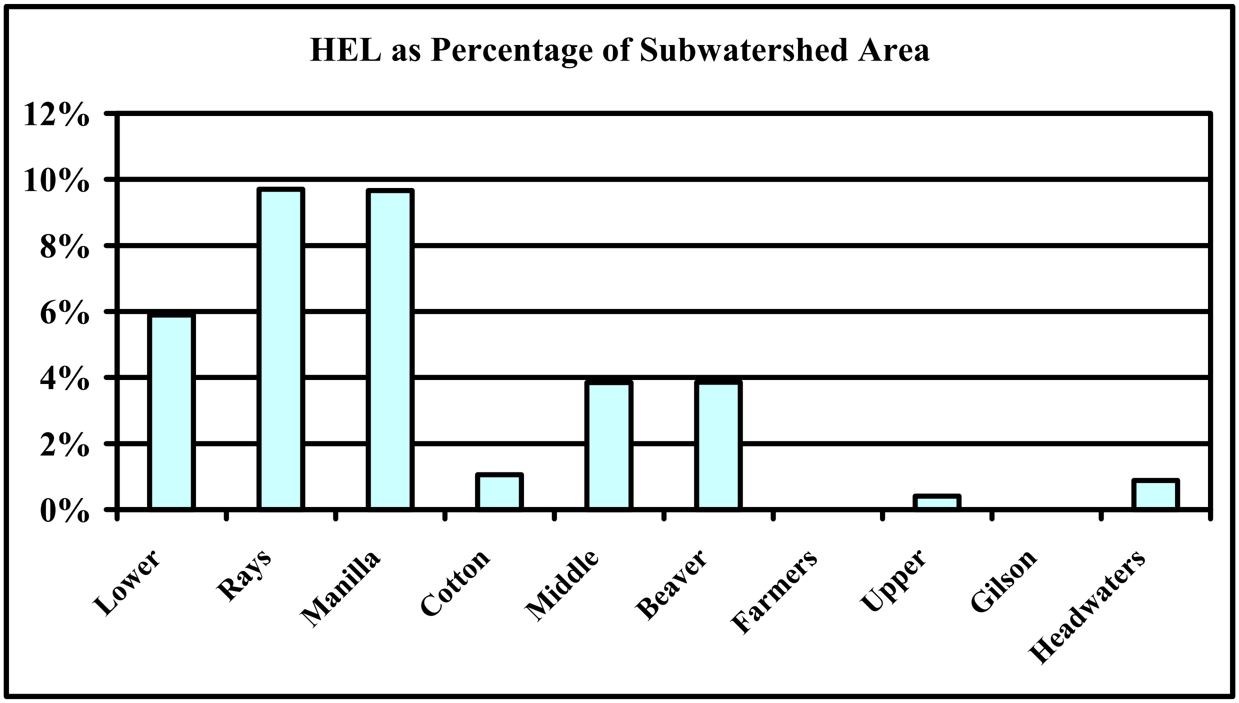


Figure 9. Highly erodible land as a percentage of subwatershed area.

When comparing Figure 8 and 11, it becomes apparent that many of the tracts mapped as HEL in the watershed are currently being used for row crop agriculture. This type of land use on highly erodible, marginal soils has definite implications for the receiving waterway's ability to support its beneficial uses. Consideration and implementation of Best Management Practices (BMPs) on these tracts is merited. BMPs will be discussed in more detail later in the report.

2.4.4 Soils Utilized for Wastewater Disposal Systems

Nearly half of Indiana's population lives in residences with private waste disposal systems. As is common in rural Indiana, septic tanks and septic tank absorption fields are utilized for wastewater treatment in the Little Blue River Watershed. This type of wastewater treatment system relies on the septic tank for primary treatment to remove solids and the soil for secondary treatment to reduce the remaining pollutants in the effluent to levels that protect surface and groundwater from contamination.

A variety of factors can affect a soil's ability to function as a septic absorption field. Seven soil characteristics are currently used to determine soil suitability for on-site sewage disposal systems: position in the landscape, slope, soil texture, soil structure, soil consistency, depth to limiting layers, and the depth to seasonal high water table (Thomas, 1996). The ability of soil to treat effluent (waste discharge) depends on four factors: the amount of accessible soil particle surface area, the chemical properties of soil surfaces, soil conditions like temperature, moisture, and oxygen content, and the type of pollutants present in the effluent (Cogger, 1989).

The amount of accessible soil particle surface area depends both on particle size and porosity. Because they are smaller, clay particles have a greater surface area per unit volume than silt or sand and therefore, a greater potential for chemical activity. However, soil surfaces only play a role if wastewater can contact them. Soils of high clay content or soils that have been compacted often have few pores that can be penetrated by water and are not suitable for septic systems because they are too impermeable. Additionally, some clays swell and expand on contact with water, closing even more spaces and pores in the profile. On the other hand, very coarse soils may not offer satisfactory effluent treatment either because the water can travel rapidly through the soil profile. Soils located on sloped land also may have difficulty in treatment of wastewater due to reduced contact time.

Chemical properties of the soil surfaces are also important for wastewater treatment. For example, clay materials all have imperfections in their crystal structure, which gives them a negative charge along their surfaces. Due to their negative charge, they can bond cations that have positive charge on their surfaces. However, many pollutants in wastewater are also negatively charged and are not attracted to the clays. Clays can help remove and inactivate bacteria, viruses, and some organic compounds.

Environmental soil conditions influence the microorganism community, which ultimately carries out the treatment of wastewater. Factors like temperature, moisture, and oxygen availability influence microbial action. Excess water or ponding saturates soil pores and slows oxygen transfer. The soil may become anaerobic if oxygen is depleted. Decomposition processes (and therefore effluent treatment) become less efficient, slower, and less complete if oxygen is not available.

Many of the nutrients and pollutants of concern are removed safely if a septic system is sited correctly. Most soils have a large capacity to hold phosphate. On the other hand, nitrate (the end product of nitrogen metabolism in a properly functioning septic system) is very soluble in soil solution and is often leached to the groundwater. Care must be taken in siting the system to avoid well contamination. Nearly all organic matter in wastewater is biodegradable as long as conditions are right. Bacteria and viruses are much smaller than other pathogenic organisms associated with wastewater and, therefore, have a much greater potential for movement through the soil. Clay minerals and other soil components may absorb them, but retention is not necessarily permanent. During storm flows, they may become resuspended in the soil solution and transported in the soil profile. Inactivation and destruction of pathogens occurs more rapidly in soils containing oxygen because sewage organisms compete poorly with natural soil mircroorganisms, which are obligate aerobes requiring oxygen for life. Sewage organisms live longer under anaerobic conditions without oxygen and at lower soil temperatures because natural soil microbial activity is reduced.

The Little Blue River Watershed

Soil conditions, such as slow permeability and high water table, coupled with poor design, faulty construction, and lack of maintenance reduce the average life span of septic systems in Indiana to 7-10 years (Jones and Yahner, 1994). Likewise, several onsite systems located in morainal soils in other areas in Indiana are known to perform poorly or to have failed completely (Indiana University/Purdue University, 1996). Localized soil-geologic conditions are responsible for most of the problems. In fact, in Wells County in northeast Indiana, the Indiana State Department of Health and the Wells County Health Board have instituted a moratorium on residential development within the Wabash end moraine in an area known as "Buttermilk

Ridge", a part of Union Township (Section 14, Township 28 North, Range 11 East). Although no extensive studies have been conducted within the Shelbyville Moraine, which extends across a portion of the Little Blue River Watershed, soil types there share similar compositional characteristics with soils found in the Wabash end moraine.

According to the Rush County Health Department, septic system failures and straight pipe discharges to surface waterbodies are decreasing every year. During the 1990s, piping of septic effluent to drainage tiles connected to surface water systems were the predominant method for treating septic waste in many of the small towns in Rush County. Nearly half of the dye tests conducted in the towns of Arlington, Homer, and Manilla indicated septic discharge to surface tiles (Ryan Cassidy, Rush County Health Department). *E. coli* samples collected near Arlington during the early to mid-1990s contained concentrations ranging from 49,000 to 8,700,000 colonies/100 ml (Donna Cloud, Rush County Sanitarian). Many *E. coli* samples collected near Homer also contained concentrations 100-150 times the Indiana state standard (235 colonies/100 ml). The dye testing and *E. coli* sampling program conducted by the Rush County Health Department prompted the formation of the Western Rush County Sewer District. Once the District is fully functioning, it will treat effluent from Arlington, Homer, and Manilla. All residences and businesses within Arlington are currently connected to the system; system hook-ups will occur in Homer during the summer of 2003; and hook-ups are tentatively scheduled to occur in Manilla during 2004 and 2005 (Ryan Cassidy, Rush County Health Department).

Septic failures in more rural portions of the watershed are also declining. No septic failures have been reported in either Shelby or Rush Counties within the past two years (William Pursley, Shelby County Health Department; Ryan Cassidy, Rush County Health Department). Mr. Pursley believes that larger lot sizes, more stringently enforced guidelines, and the abandonment of old, poorly-functioning septic systems have helped curtail septic system problems within Shelby County. Mr. Cassidy stated that education efforts on the part of the Western Rush County Sewer District and the Rush County Health Department have helped to curtail septic problems throughout Rush County.

The NRCS ranks each soil series in terms of its limitations for use as a septic tank absorption field. Each soil series is placed in one of three categories: slightly limited, moderately limited, or severely limited. Use of septic absorption fields on soils in the moderately to severely limited categories generally requires special designs, planning or maintenance to overcome the limitations. Table 7 summarizes the soil series located in the study area in terms of their suitability for use as a septic tank absorption field.

Table 7. Soil types present in the Little Blue River Watershed and their suitability for on-site wastewater treatment systems.

County	Name	Symbol*	Depth to Water Table	Suitability for Septic Absorption Field
Henry	Cyclone silty clay loam	Cy	+0.5-1.0 ft	Severe: ponding
Henry	Eldean silt loam	EdA; EdB2	>6 ft	Severe: poor filter
Henry	Losantville silt loam	LeB2	4-6 ft	Severe: percs slowly
Henry; Rush	Eldean clay loam	ElC3; ExC3	>6 ft	Severe: poor filter

County	Name	Symbol*	Depth to Water Table	Suitability for Septic Absorption Field
Henry; Rush; Shelby	Sleeth silt loam	Sk; Sm	1-3 ft	Severe: wetness; seasonal high water table
Henry; Shelby	Westland clay loam	Wc; We	0-1 ft	Severe: percs slowly; ponding; seasonal high water table
Rush	Celina silt loam	CeB2	2-3.5 ft	Severe: wetness; percs slowly
Rush	Eldean loam	EdB2	>6 ft	Severe: poor filter
Rush	Genesee loam	Ge	3-6 ft	Severe: flooding; wetness
Rush	Miamian silt loam	MpB2; MpC-MpE	>6 ft	Severe: percs slowly; slope
Rush	Miamian clay loam	MuC3-MuD3	>6 ft	Severe: percs slowly; slope
Rush	Patton silty clay loam	Pn	+0.5-2 ft	Severe: percs slowly; ponding
Rush	Sloan silt loam	So	0-1 ft	Severe: flooding; percs slowly; wetness
Rush	Treaty silty clay loam	Tr	+0.5-1 ft	Severe: ponding; percs slowly
Rush	Westland clay loam	Ws	+0.5-1 ft	Severe: ponding
Rush; Shelby	Crosby silt loam	CrA-CrB	1-3 ft	Severe: wetness; percs slowly; seasonal high water table
Rush; Shelby	Miami silt loam	MrA; MlA	>6 ft	Moderate: percs slowly
Rush; Shelby	Ockley silt loam	OcA; OcB2	>6 ft	Slight: some hazard of polluting nearby wells
Rush; Shelby	Shoals silt loam	Sh; Sk	0.5-1.5 ft	Severe: wetness; flooding; seasonal high water table
Shelby	Brookston silty clay loam	Br	0-1 ft	Severe: percs slowly; ponding; seasonal high water table
Shelby	Crosby-Miami silt loam	CsB	1-3 ft	Moderate-Severe: percs slowly; ponding; seasonal high water table
Shelby	Eel silt loam	Ee	3-6 ft	Severe: flooding
Shelby	Fox loam	FoA-FoB2	>6 ft	Slight: 0-6% slopes; some hazard of polluting nearby wells Moderate-Severe: 6-18% slopes due to rapid drainage
Shelby	Fox clay loam	FxB3	>6 ft	Slight (some hazard of polluting nearby wells)
Shelby	Genesee loam	Ge	>6 ft	Severe: flooding
Shelby	Gravel pits	Gp	--	
Shelby	Hennepin loam	HeE-HeF	>6 ft	Severe: steep slopes
Shelby	Martinsville loam	MaA-MaB2	>6 ft	Slight: 0-6% slopes; some hazard of polluting nearby wells Moderate: 6-12% slopes due to rapid drainage
Shelby	Medway silt loam	Me	3-6 ft	Severe: flooding
Shelby	Miami clay loam	MmB3-MmD3	>6 ft	Moderate: 0-12% slopes due to slow permeability Severe: 12-18% slopes due to steep slopes

County	Name	Symbol*	Depth to Water Table	Suitability for Septic Absorption Field
Shelby	Nineveh loam	NnA	>6 ft	Slight: some hazard of polluting nearby wells
Shelby	Rensselaer clay loam	Re	0-1 ft	Severe: percs slowly; ponding; high seasonal water table
Shelby	Rodman gravelly loam	RoE	>6 ft	Severe: steep slopes
Shelby	Ross silt loam	Rt	>6 ft	Severe: flooding
Shelby	Saranac silty clay loam	Sa	0-1 ft	Severe: percs slowly; ponding: seasonal high water table
Shelby	Whitaker loam	Wh	1-3 ft	Severe: ponding; seasonal high water table

*Different counties may use the same symbol for different soil units. Similarly, different counties may use different symbols for the same soil units.
Source: Brock, 1986; Hillis and Neely, 1987; Brownfield, 1991.

Of the soil types present in the study drainage, Ockley silt loam (OcA; OcB2), Fox clay loam (FxB3), and Nineveh loam (NnA) soils rated as slightly limited for usage as septic leachate field. Some risk of polluting nearby wells is associated with these soils. Fox (FoA-FoB2) and Martinsville loam (MaA) soils are also slightly limited for treatment as long as they are situated on slopes of less than 6%. Systems installed on slopes steeper than 6% are rapidly drained, resulting in improper leach field functioning. Miami clay loam (MmB3-MmC3), Martinsville loam (MaB2), and Miami silt loam (MrA) soils are moderately limited for usage as septic leachate fields.

The remaining soil types are severely limited for use as septic system substrate and are generally not conducive to the satisfactory operation of conventional on-site treatment systems. Eldean loam (EdB2), silt loam (EdA, EdB2), and clay loam (ElC3; ExC3) soils tend to be poorly drained with poor filtering capacity. Cyclone (Cy), Patton (Pn), Treaty (Tr), and Brookston (Br) silty clay loams and Rensselaer (Re) and Westland (Wc; We) clay loams are severely compromised for septic effluent treatment. The water table is often within one foot of the surface of these soils, and because the water table is often at the same level as surface water features (streams and rivers), achieving proper septic field drainage may be impossible. Soils belonging to the Miamian series (MpB2, MpC-MpE, and MuC3-MuD3) are limited due to prolonged periods of wetness and by steep slopes. Eel (Ee), Ross (Rt), and Medway (Me) silt loam and Genesee loam (Ge) soils are prone to flooding from adjacent streams. Sloan (So), Celina (CeB2), Losantville (LeB2), and Crosby (CrA-CrB) silt loam soils are limited by flooding, slow drainage, and prolonged periods of wetness. Sleeth silt loam (Sm) soils tend to be wet, poorly drained soils. Saranac silty clay loam (Sa), Crosby-Miami (CsB) and Shoals (Sh; Sk) silt loam, and Whitaker loam (Wh) soils are severely limited due to seasonal high water tables. High water tables, especially during wet seasons, can cause soil saturation and even ponding. Characteristic wetness can lead to anoxic conditions and improper treatment within leach fields. It is recommended that systems be installed with perimeter surface drains to lower the water table, installed with an enlarged leach field to offset slow permeability, and constructed when the soil is dry to avoid soil sealing and compaction. Hennepin loam (HeE-HeF) and Rodman gravelly loam (RoE) soils are severely limited for septic leach field placement due to steep slopes. These soils are severely limited because drainage time is too rapid to allow for filtration. Poor filtration and treatment may compromise groundwater quality.

Many of the soil types in the study watershed have severe limitation for septic suitability (Table 7). Geologic conditions in many parts of the diffuse moraine deposits are not likely to promote satisfactory septic system function resulting in surface and groundwater pollution. Although no septic inspections or sampling were conducted as part of this study, stream water quality sampling does not rule out improperly functioning systems as a possible cause of surface water pollution in the watersheds, particularly in samples were *E. coli* concentrations during storm water runoff exceeded 5,000 col/100 ml. Additionally, elevated levels of *E. coli* have been measured in historic water quality samples collected throughout the Little Blue River Watershed.

To address water quality issues associated with the use of septic systems, residential development that relies on septic systems for treatment of wastewater should proceed with caution, especially in soils unsuited for conventional septic treatment systems. Competent soil scientists that are familiar with conditions should evaluate potential development sites for evidence of poor water movement, soil development, or filtering ability. Alternative technology, like the mound system, the at-grade system, the pressure-dosed system, or wastewater wetland may provide a solution in soils that are unsuitable. Some soils may be suitable for alternating field technology, which requires that a second field be available to accept effluent while the primary field “rests”. Enlarged septic fields should be installed to increase the area of absorption. It is important to note, however, that some soils are too wet, too shallow, too impermeable, too steep, or too well-drained for any type of system.

Once the proper technology has been installed, proper maintenance is very important. Depending on the size of the system and the loading to it, systems should be cleaned every 2 to 5 years. Property owners should divert surface runoff away from absorption fields, keep a cover of vegetation over the field, and keep foot and vehicular traffic over the field to a minimum. Pressure on septic systems can also be reduced by common water conservation practices like shorter showers and less flushing and rinsing, within reason.

2.4.5 Soil Summary

The type of soils in a watershed and the land uses practiced on those soils can impact the quality of the water in the watershed. Soil erosion contributes sediment to waterways reducing water quality downstream, degrading aquatic habitat, and interfering with recreational uses. Nutrients attached to eroded soils fertilize and increase aquatic production. Additionally, soil eroding from the landscape accumulates in ditches and drainageways necessitating costly dredging maintenance projects. Not only does the sediment hinder water conveyance, it also provides a nutrient-rich substrate for rooted aquatic plant growth. Nutrients and nutrient-rich sediment can promote the growth of nuisance levels of algae and plants downstream in other waterbodies. Consequently, conservation methods and best management practices should be utilized when soils are disturbed in these areas. This includes residential development and farming practices in highly erodible soils.

Soil type should also be considered in siting septic systems. Some soils do not provide adequate treatment for septic tank effluent. Much of the land in the study watersheds is mapped in soils that rate as severely limited or generally unsuitable for use as septic tank absorption fields. This is typical for much of Indiana, as research by Dr. Donald Jones suggests that 80% of the soils in Indiana are unsuitable for wastewater treatment (Grant, 1999).

Pollution from septic tank effluent can affect waterways, the life the waterways support, and the users of these waterways in a variety of ways. It can contribute to eutrophication (overproduction) and water quality impairment of creeks and other waterbodies in the watershed. In addition, septic tank effluent potentially poses a health concern for users of both surface and groundwater in the watershed. Swimmers, anglers, or boaters that come in contact with contaminated water may be exposed to waterborne pathogens. This is an issue of concern for the Little Blue River, its tributaries, and its receiving waterbody, the Big Blue River, since according to Indiana State statutes, these waterbodies should support contact recreation as a beneficial use (IDEM, 2000; IAC, 2000). Fecal contaminants can be harmful to humans and cause serious diseases, such as infectious hepatitis, typhoid, gastroenteritis, and other gastrointestinal illness. Additionally, nitrogen and pathogens may also leach into the groundwater compromising drinking water.

2.5 POPULATION AND DEMOGRAPHICS

Measuring and tracking population growth in the watershed is difficult since governmental and other agencies measuring this data often report their findings on a township, county, or census tract basis rather than by watershed. However, the reported data can be utilized to estimate the current watershed population and track its growth over the past century. Table 8 presents the U.S. Census data for the Little Blue River Watershed area from 1890 to 2000. The northern portion of the watershed lies in Spiceland Township in Henry County and Center, Jackson, Posey, and Walker Townships in Rush County, while the southern portion of the watershed lies in Addison, Marion, and Union Townships in Shelby County. These are divided by county in Figure 10.

Table 8. U.S. Census data for the townships and counties in which the Little Blue River Watershed is located.

	1890	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000
Shelby County	**25,454**	**26,491**	**26,802**	**25,982**	**26,552**	**25,953**	**28,026**	**34,093**	**37,797**	**39,887**	**40,307**	**43,445**
Addison Township	6,909	8,671	10,655	11,063	12,275	12,359	13,857	16,904	17,790	17,334	17,577	19,943
Marion Township	943	868	767	671	695	593	617	701	921	1,326	1,384	1,534
Union Township	1,169	1,100	997	938	851	849	802	848	859	782	859	944
Rush County	**19,034**	**20,148**	**19,349**	**19,241**	**19,412**	**18,927**	**19,799**	**20,393**	**20,352**	**19,604**	**18,129**	**18,261**
Center Township	1,071	1,753	1,544	1,376	1,721	1,771	1,626	1,316	1,440	1,177	1,025	768
Jackson Township	789	706	659	582	593	513	524	454	466	435	381	415
Posey Township	1,708	1,495	1,382	1,299	1,226	1,154	1,114	1,113	1,178	1,271	1,194	1,189
Walker Township	1,334	1,361	1,173	1,192	1,104	991	1,075	1,146	1,100	1,057	966	916
Henry County	**--**	**25,088**	**29,758**	**34,682**	**35,238**	**40,208**	**45,505**	**48,899**	**52,603**	**53,336**	**48,139**	**48,508**
Spiceland Township	1,823	1,844	1,822	1,786	1,678	1,799	2,005	2,257	2,400	2,365	2,270	2,200

Source: Stats Indiana, 2003.

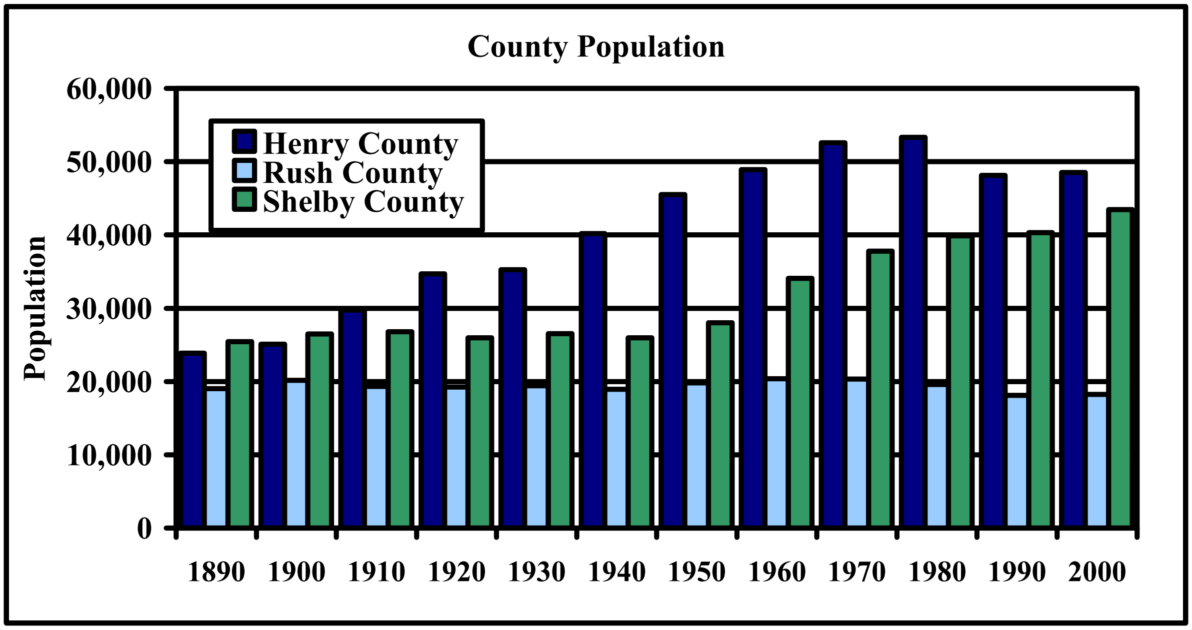


Figure 10. Population trend in Henry, Rush, and Shelby Counties.

Marion and Addison Townships in Shelby County have shown steady growth over the past 60 years. Marion Township in Shelby County experienced its greatest growth rate between 1970 and 1980 when the township's population grew by 44%. Addison Township's greatest growth rates occurred between 1890 and 1910 and again between 1960 and 1970 when populations grew by 25 and 22%, respectively. Shelby County's population has also grown steadily throughout the past century increasing by 70% from 25,454 in 1890 to 43,445 in 2000. Growth in the City of Shelbyville has undoubtedly played a role in the population growth of both Addison Township and Shelby County. Conversely, populations in Rush County have decreased by 4% over the last century. Declines in populations of Rush County townships within the watershed are much greater than those observed throughout all of Rush County; populations decreased by 28-47% in Center, Jackson, Posey, and Walker Townships in the past 110 years.

Growth remains stronger in Shelby County than in Rush County. Table 9 shows the current population, state rank, and recent growth rate for Shelby and Rush Counties as well as for the townships in which the Little Blue River Watershed is located. Shelby County is the thirty-third most populated county in the state while Rush County is the seventy-sixth most populated county. Addison Township ranks 61st (out of approximately 1000 townships) in terms of population density while Marion and Union Townships in Shelby County and Center, Jackson, Posey, and Walker Townships in Rush County rank in the bottom half of the population density standings. Jackson Township ranks 960th and is one of the most sparsely populated townships in Indiana. Both Shelby and Rush Counties saw an increase in population from 1990 to 2000; Shelby County's population increased by 7.8%, while Rush County's population increased by 0.7%. This data indicates population growth in the lower portion of the Little Blue River Watershed is outpacing the average growth in both counties.

Table 9. Current population, state rank, and recent growth rate for the townships and counties in which the Little Blue River Watershed is located.

	Census 2000		Census 1990			
	Total	Rank	Total	Rank	Change	Percent Change
Shelby County	**43,445**	**33**	**40,307**	**30**	**3,138**	**7.8%**
Addison	19,943	65	17,577	61	2,366	13.5%
Marion	1,534	582	1,384	593	150	10.8%
Union	944	791	859	799	85	9.9%
Rush County	**18,261**	**76**	**18,129**	**75**	**132**	**0.7%**
Center	768	854	1,025	721	-257	-25.1%
Jackson	415	960	381	968	34	8.9%
Posey	1,189	707	1,194	670	-5	-0.4%
Walker	916	801	966	748	-50	-5.2%
Henry County	**48,508**	**27**	**48,139**	**25**	**369**	**0.8%**
Spiceland	2,200	437	2,270	394	-70	-3.1%

Source: Stats Indiana, 2003.

The lower portion of the Little Blue River Watershed supports nearly twice the population observed in the upper portion of the watershed. Addison Township houses approximately 550 people per square mile, while only 12 people per square mile live in Jackson and Spiceland Townships (Table 10). On average, 91 people per square mile live in the eight townships encompassed by the Little Blue River Watershed.

Table 10. Population structure for the seven townships that are fully or partially encompassed by the Little Blue River Watershed.

County	Township	Township Population	People/Square Mile
Shelby	Addison	19,943	554
Shelby	Marion	1,534	43
Shelby	Union	944	26
Rush	Center	768	21
Rush	Jackson	415	12
Rush	Posey	1,189	33
Rush	Walker	916	25
Henry	Spiceland	437	12
All Counties		**26,146**	**91**

Source: Stats Indiana, 2003.

2.6 LAND USE

Figure 11 and Table 11 present land use information for the Little Blue River Watershed. Land use data was obtained from the USGS EROS Land Use Data coverage. The EROS Land Use Data coverage was last corrected to reflect current conditions during December 1998. As a part of this study, the EROS data was checked with recent aerial photography and in some areas was field checked and corrected to reflect watershed conditions as of 2003. Land use data for each subwatershed is presented in Appendix B.

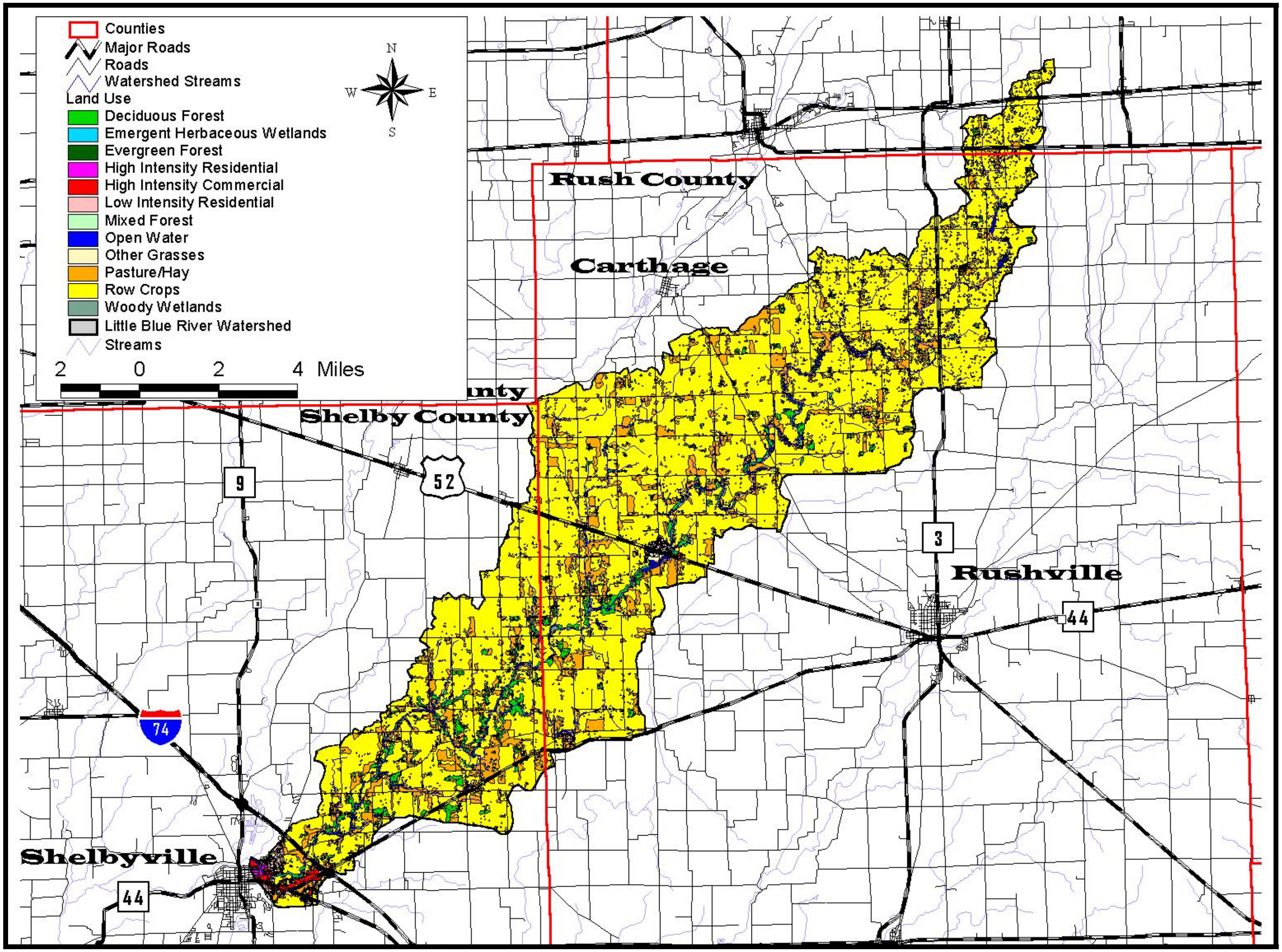


Figure 11. Land use in the Little Blue River Watershed. Source: See Appendix A.

Table 11. Land use in the Little Blue River Watershed.

	Area (acres)	Area (hectares)	Percent of Watershed
Agriculture Row Crop	53,336.2	21,593.6	79.04%
Agriculture Pasture/Hay	10,037.7	4,063.9	14.88%
Deciduous Forest	2,711.5	1,097.8	4.02%
Woody Wetlands	369.9	149.8	0.55%
Low Intensity Residential	337.4	136.6	0.50%
High Intensity Commercial	335.9	136.0	0.50%
Urban Parkland	150.0	60.7	0.22%
High Intensity Residential	91.1	36.9	0.13%
Open Water	56.4	22.8	0.08%
Emergent Herbaceous Wetlands	52.7	21.3	0.08%
Evergreen Forest	1.8	0.7	<0.01%
Mixed Forest	0.4	0.2	<0.01%
Little Blue River Watershed	**67,483**	**27,320**	**100%**

2.6.1 Agricultural Land Use in the Watershed

Approximately 94% of the watershed is used for agricultural purposes, including cropland, pasture, and small grain production. This percentage is higher than that estimated by the U.S. Census of Agriculture (1997) for Shelby (77%), Rush (87%), and Henry (70%) Counties. Because the watershed is located in a rural area and includes only a small portion of Shelbyville, more land is used for cultivation than is average for the counties. Table 12 contains more detailed U.S. Census of Agriculture (1997) data for the three counties.

Table 12. Detailed U.S. Census of Agriculture data for Henry, Rush, and Shelby Counties.

County	Year	# of Farms	# Full-time Farms	Average Farm Size (acres)	Land in Farms	% of County Farmed
Henry County	1987	938	490	198	186,172	73.7%
	1992	848	393	225	190,798	75.6%
	1997	770	319	231	177,601	70.3%
Rush County	1987	834	584	287	239,641	91.7%
	1992	761	517	306	233,183	89.3%
	1997	663	428	344	227,874	87.2%
Shelby County	1987	876	203	249	217,961	83.3%
	1992	749	425	290	217,288	83.0%
	1997	641	336	313	200,661	76.7%

Source: Brock, 1986; Brownfield, 1991; U.S. Census of Agriculture, United States Department of Commerce, 1997.

The number of farms and the total acreage of land utilized for farming has steadily declined in Henry, Rush, and Shelby Counties. Over the last ten years the number of farms in Henry County has declined from 938 farms in 1987 to 770 farms in 1997 (18%) while the number of farms in Rush County has declined from 834 farms in 1987 to 663 farms in 1997 (20%); a 27% decrease in the number of farms was observed in the Shelby County in the last ten years dropping from 876 farms in 1987 to 641 farms in 1997 (Figures 12-14). The decline in the number of farms in the three counties corresponds with a 27% decrease in the number of full-time farmers in Rush County and a 36% decline in the number of full-time farmers in Henry and Shelby Counties. Conversely, average farm size increased from 198 acres in 1987 to 231 acres (17%) in 1997 in Henry County, from 287 acres to 344 acres in Rush County (20%), and from 249 to 313 acres (26%) in Shelby County (Table 12). These observations mirror nationwide full-time farmer and farm size trends observed throughout the late 1980's and early 1990's. As maintaining individual farms became more difficult, the number of individuals maintaining family farms decreased. Much of the farmland has remained in production; however, large factory-type farms managed by absentee landowners replaced smaller, family managed farms (Arenberg et al., 2003). If the counties mirror national trends, then the minor decreases in the percent of Henry, Rush, and Shelby Counties being farmed, 5%, 5%, and 8%, respectively, coincide with the conversion of family farms with on-site management to factory farms run by absentee landowners (Table 12; Figures 12-14). This conversion can be observed throughout the Little Blue River Watershed by the increase in the average farm size in Henry (17%), Rush (20%), and Shelby (26%) Counties from 1987 to 1997 (Figures 12-14). Overall, decreases in the acreage of land in farms, the number of farm, and the number of full time farmers and increases in the average farm size were more pronounced in Shelby County than in Rush and Henry Counties, which may be due to urban growth in and around Shelbyville.

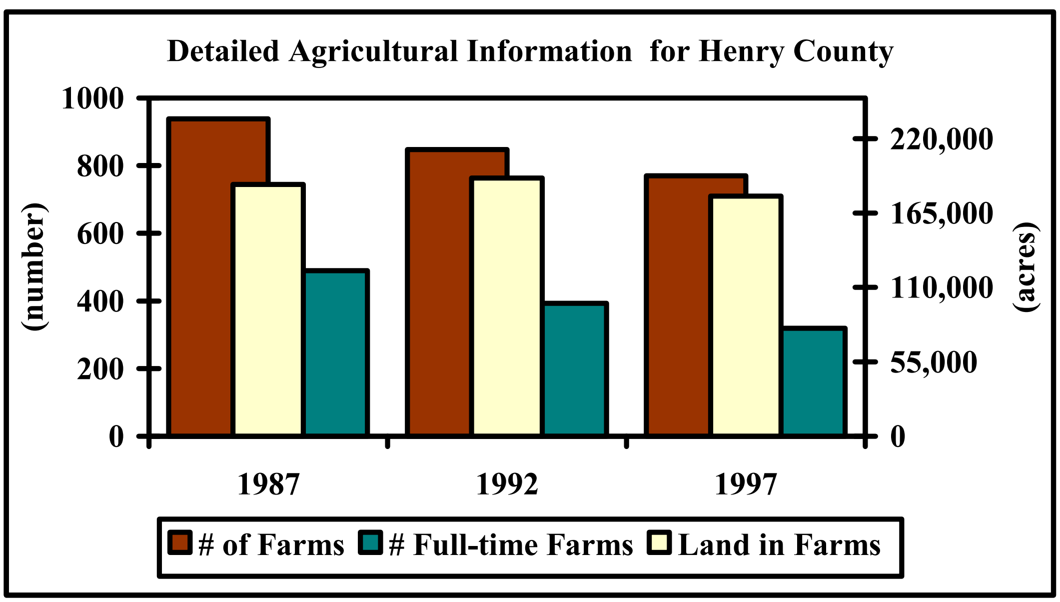


Figure 12. Number of farms, full time farms, and land in farms in Henry County.

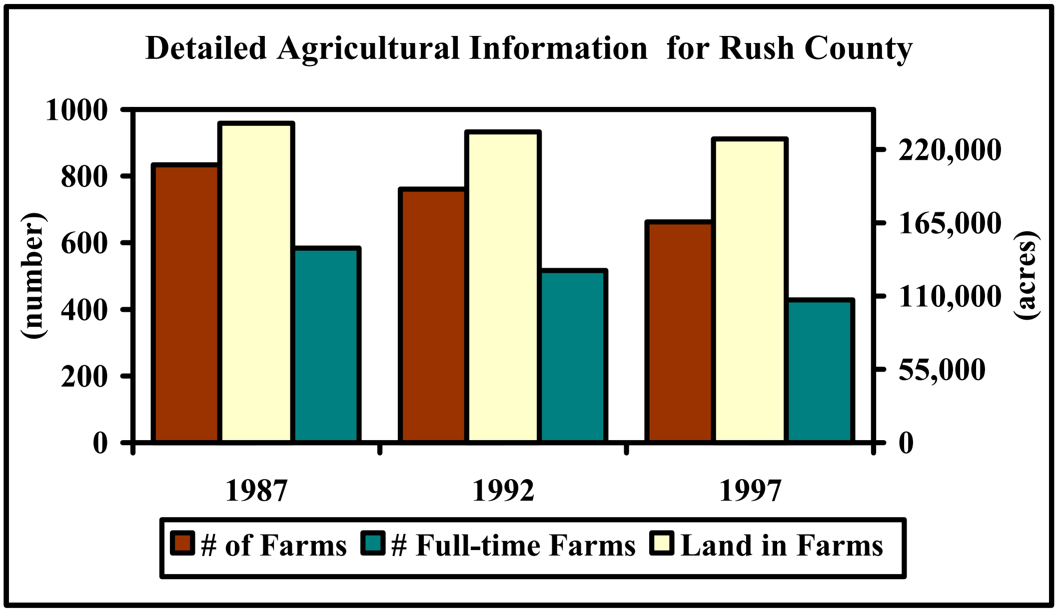


Figure 13. Number of farms, full time farms, and land in farms in Rush County.

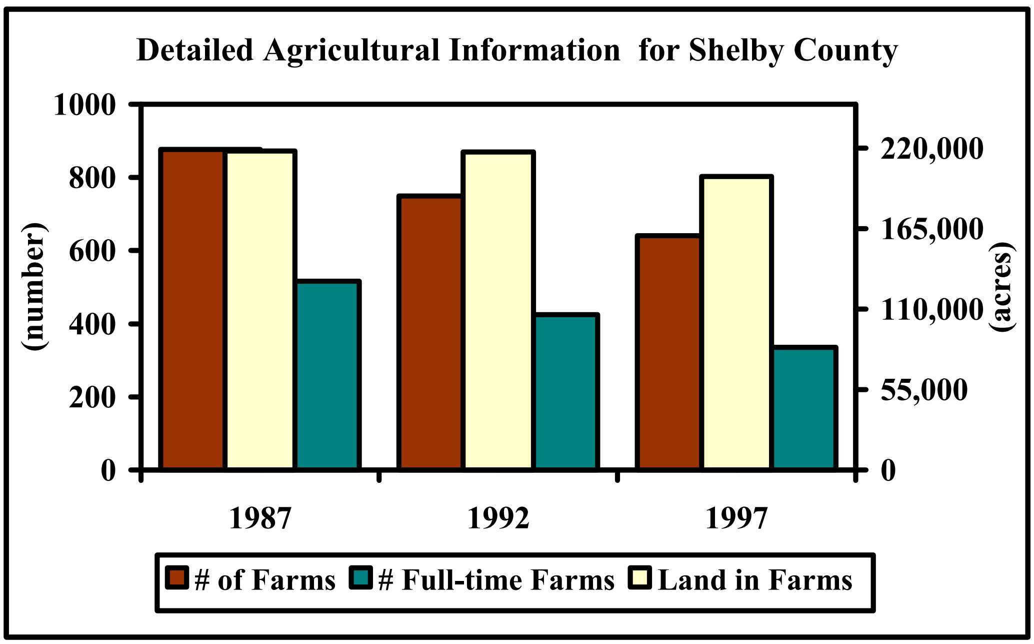


Figure 14. Number of farms, full time farms, and land in farms in Shelby County.

Soybeans, corn, small grains, and forage are the major crops grown in Shelby, Rush, and Henry Counties. Although exact percentages of each crop were not recorded for the study watershed, between 40 and 50% of the agricultural fields in the counties were planted with corn and 39 to 46% in soybeans in 2002 (Purdue University Cooperative Extension Service, 2003). Table 13 contains more detailed information regarding percentage and acreage of Shelby, Rush, and Henry County fields used to produce different crops and commodities in 2002 and estimated numbers of cattle in 2003. Note that Henry, Shelby, and Rush Counties rank thirty-eighth, thirty-ninth, and eighth, respectively, in the state for swine production.

Table 13. Percent and acreage of Henry, Rush, and Shelby County fields with indicated present crop for year 2002. Percentages are taken from a field sampling of points along transects across the counties. No data are available for percent or acreage of land in permanent pasture. The estimated number of beef cattle, dairy cattle, total cattle, and swine in the counties in 2003 are also given. The last column provides production rank for each county in the state for each of the commodities.

Crop/Commodity	Percent or Number	Acreage of Land	Rank in State
Henry County			
Soybeans		82,100	24
Corn		75,900	30
Small Grains		3,200	30
Hay/Forage		3,750	34
Beef Cattle	2,900		
Dairy Cattle	1,300		
Total Cattle	9,600		32
Swine	35,000		38
Rush County			
Soybeans		98,500	6
Corn		104,300	7
Small Grains		4,300	20
Hay/Forage		5,300	44
Beef Cattle	2,600		
Dairy Cattle	1,400		
Total Cattle	11,900		26
Swine	119,000		8
Shelby County			
Soybeans		93,900	14
Corn		101,400	12
Small Grains		3,800	27
Hay/Forage		3,100	73
Beef Cattle	1,400		
Dairy Cattle	700		
Total Cattle	5,900		65
Swine	41,200		39

Source: Mark Evans, Purdue Cooperative Extension Agency; Indiana Agricultural Statistics, 2003.

Conservation Reserve Program in the Little Blue River Watershed

Landowners in the Little Blue River Watershed currently utilize a variety of “set aside” practices on agricultural land. These “set aside” or conservation practices include the use of filter strips, grassed waterways, and wildlife set-asides. Figure 8 shows where these practices are currently used in the Little Blue River Watershed. Table 14 contains acreages of land enrolled in the Conservation Reserve Program (CRP) within the Little Blue River Watershed. Of the mainstem subwatersheds, the Middle Little Blue River Subwatershed contains the largest acreage currently enrolled in the CRP. Both the Upper and Lower Mainstem Subwatersheds contain tracts enrolled in the CRP. However, only two tributary subwatersheds, the Manilla Branch Subwatershed and the Headwaters Subwatershed contain tracts enrolled in the CRP. Of all the subwatersheds with land enrolled in the program, less than 1% of the Little Blue River Watershed is enrolled in the CRP.

Table 14. Acreages of land enrolled in the CRP by subwatershed.

Subwatershed	Acres	Hectares	Percent of Watershed	HEL:CRP
Lower Little Blue River Subwatershed	33.75	13.6	0.08%	100:1
Rays Crossing Tributary Subwatershed	0.0	0.0	0%	243:0
Manilla Branch Subwatershed	1.25	0.5	0.04%	226:1
Cotton Run Subwatershed	20.0	8.1	0.90%	1.2:1
Middle Little Blue River Subwatershed	37.8	15.3	0.63%	8:1
Beaver Meadow Creek Subwatershed	0.0	0.0	0%	485:0
Farmers Stream Subwatershed	0.0	0.0	0%	0:0
Upper Little Blue River Subwatershed	19.8	8.0	0.09%	4.8:1
Little Gilson Creek Subwatershed	0.0	0.0	0%	0:0
Headwaters Subwatershed	19.8	8.0	0.21%	5:1
Little Blue River Watershed	**66.4**	**26.9**	**0.09%**	**25:1**

Source: Farm Service Agencies of Rush and Shelby Counties.

A comparison of CRP set-asides and HEL designations can help to determine areas where management may be best targeted. Some CRP set-asides within the study watershed overlap with land that is highly erodible (Figure 9); however, some watersheds, like Beaver Meadow Creek and Rays Crossing Tributary Subwatersheds, contain HEL but not CRP. The small acreage of HEL (23.3 acres) within the Cotton Run Subwatershed is almost entirely treated with CRP enrollment. The Farmers Stream, Little Gilson Creek, and Upper Little Blue River Subwatersheds contain no HEL and also no CRP. Of the subwatersheds containing both HEL and CRP, the Cotton Run and Headwaters Subwatersheds contain the lowest HEL:CRP ratios (1.2:1 and 5:1, respectively), while the Manilla Branch Subwatershed contains the highest (226:1). This means that for every 226 acres of HEL only one acre is designated CRP. Future CRP enrollment should focus on the HEL within the Manilla Branch, Rays Crossing Tributary, and Beaver Meadow Creek Subwatersheds and along the mainstem of the Little Blue River.

Some non-protected HEL tracts directly border streams within the watershed. HEL tracts that adjoin streams are located within the Rays Crossing Tributary, Manilla Branch, and Beaver Meadow Creek Subwatersheds and along the mainstem of the Little Blue River. These tracts would be optimal sites for CRP or other program enrollment.

Conservation Tillage in the Little Blue River Watershed

Some agricultural landowners in the Little Blue River Watershed also utilize conservation tillage on their property. Conservation tillage offers the potential for reducing erosion without removing the land from production. Conservation tillage is a crop residue management system that leaves at least one-third of the soil covered with crop residue after planting. While conservation tillage patterns were not estimated for the study watershed, they are in use throughout Henry, Rush, and Shelby Counties and on many fields within the watershed. (The Agricultural Best Management Practices Section contains detailed information about conservation tillage types.) Table 15 shows conservation tillage usage patterns in the growing season of 2002 for Henry, Rush, and Shelby Counties, while Table 16 displays conservation tillage usage patterns in the 2003 growing season for Shelby County. Henry and Rush Counties did not conduct tillage transect surveys in 2003.

Table 15. Percent (number) of crop fields with tillage systems in the growing season of 2002 for Henry, Rush, and Shelby Counties. N/A refers to those fields where the field was not tilled. Unknown (Unk.) refers to those fields where tillage type could not be determined.

County	No-till	Ridge-till	Mulch-till	Reduced-till	Conventional-till	N/A	Unk.
Corn							
Henry	25 (56)	0 (0)	6 (13)	21 (45)	47 (102)	0 (0)	0 (0)
Rush	19 (53)	0 (1)	0 (1)	4 (12)	76 (213)	0 (0)	1 (2)
Shelby	23 (46)	0 (0)	6 (12)	8 (17)	62 (124)	0 (0)	0 (1)
Soybeans							
Henry	66 (161)	0 (0)	10 (25)	2 (4)	22 (54)	0 (0)	0 (0)
Rush	57 (126)	0 (0)	6 (14)	10 (21)	26 (58)	0 (0)	0 (1)
Shelby	75 (151)	0 (0)	1 (3)	6 (12)	17 (35)	0 (0)	0 (0)
Small Grain							
Henry	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	100 (13)	0 (0)
Rush	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	100 (11)	0 (0)
Shelby	20 (1)	0 (0)	0 (0)	0 (0)	20 (1)	40 (2)	20 (1)
Hay/Forage							
Henry	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	100 (31)	0 (0)
Rush	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	100 (27)	0 (0)
Shelby	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	100 (21)	0 (0)
Fallow/Other							
Henry	0 (0)	0 (0)	0 (0)	0 (0)	17 (5)	24 (7)	55 (16)
Rush	0 (0)	0 (0)	0 (0)	0 (0)	24 (4)	76 (13)	0 (0)
Shelby	19 (5)	0 (0)	0 (0)	0 (0)	11 (3)	0 (0)	70 (19)

Source: Purdue Cooperative Extension Service, 2002.

Table 16. Percent (number) of crop fields with tillage systems in the growing season of 2003 for Shelby County. Henry and Rush Counties did not conduct tillage transects during 2003. N/A refers to those fields where the field was not tilled. Unknown (Unk.) refers to those fields where tillage type could not be determined.

County	No-till	Ridge-till	Mulch-till	Reduced-till	Conventional-till	N/A	Unk.
Corn							
Shelby	49 (105)	0 (0)	2 (5)	5 (11)	44 (94)	0 (0)	0 (0)
Soybeans							
Shelby	89 (170)	0 (0)	5 (9)	3 (5)	4 (8)	0 (0)	0 (0)
Small Grain							
Shelby	20 (1)	0 (0)	0 (0)	0 (0)	20 (1)	40 (2)	20 (1)
Hay/Forage							
Shelby	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	100 (18)	0 (0)
Fallow/Other							
Shelby	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	100 (18)

Source: Purdue Cooperative Extension Service, 2003.

Producers in Henry, Rush, and Shelby Counties grew much of their corn and soybean crops using a conservation tillage method. In the three counties, producers utilized conventional-till methods on the majority of the land used for corn production, while most soybean producers utilized no-till methods (Purdue Cooperative Extension Service, 2003). While no-till was the most commonly used conservation tillage technique, mulch till and reduced till were also used in the Little Blue River Watershed. In general small grains were grown on soils that were conventionally tilled. Of the 92 counties in Indiana, Henry County ranked 24th and 23rd for percent of corn and soybeans, respectively, planted using a no-till system in 2002; Rush County ranked 18th and 27th for percent of corn and soybeans, respectively, in 2002 (Purdue Cooperative Extension Service, 2003). Shelby County ranked 16th and 7th for percent of corn and soybeans, respectively in 2002 and 11th and 4th in 2003. (Only 56 of the 92 counties conducted tillage transect surveys during 2003.) These numbers suggest that in general, producers in the three counties are doing better than their peers statewide in utilizing conservation tillage; however, more producers could be utilizing conservation tillage methods in the study counties. If producers did so, their efforts would likely improve water quality in the watershed.

Prime Farmland

Prime farmland is one of several land types classified and recognized by the USDA. Prime farmland is land that is best suited for crops. The land is used for cultivation, pasture, woodland or other production, but it is not urban land or water areas. This type of land produces the highest yields with minimal inputs of energy and economic resources. Farming it results in the least damage to the environment. Therefore, when possible, the optimal land use strategy places industrial and residential development on the marginal lands while keeping prime farmland available for production. According to the USDA soil surveys of Henry, Rush, and Shelby Counties, approximately 75-80% of the acreage in the area meets prime farmland requirements; the majority of the land in the central and southern portions of the Little Blue River Watershed is classified as prime farmland.

"A recent trend in land use in some parts of the county has been the loss of some prime farmland to industrial and urban uses. The loss of prime farmland to other uses puts pressure on marginal lands, which generally are more erodible, wet or droughty, and less productive and cannot be as easily cultivated" (Brock, 1986). Cultivation of more marginal land also results in more damage to the environment. Although the Little Blue River Watershed is not undergoing rapid urbanization new development in and around Shelbyville has been noted during various site visits. This type of change in land use will have obvious impacts on water quality, especially if it results in more farming of marginal land. Again, careful land use and development planning can minimize the need to produce crops on marginal land.

Confined Feeding Operations

Five separately owned farms are currently regulated to operate confined feeding operations (CFOs) within the Little Blue River Watershed. CFOs are defined by the state of Indiana as those operations where animals are confined for more than 45 consecutive or non-consecutive days per year; a majority (>50%) of the confinement area is non-vegetated; and the number of animals exceeds 300 cattle, 600 swine, 600 sheep, or 30,000 fowl (IDEM, 2002). CFOs must operate within predetermined performance standards. The standards have four main targets: to avoid management practices which discharge pollutants to state's waters; to minimize non-point source pollution to state's waters; to design, construct, and maintain waste management systems to prevent the discharge of manure and other controlled waste; and to stage and apply manure in a manner which prevents nutrient runoff, ponding, or spills and minimizes nutrient leaching beyond the root zone.

Each of the CFOs in operation within the Little Blue River Watershed (Figure 15) has completed the IDEM confined feeding operation application package. The application package must include a completed application form, plat maps locating the confined feeding operation, waste management system drawings, information from a minimum of two soil test holes, and engineer-certified drawings for any new earthen, liquid manure storage structures. Additionally, the application package must contain a farmstead plan and a manure management plan. The farmstead plan must accurately indicate locations of all structures and land features such as residences, surface waters, drainage inlets, roads, wells, and property boundaries, and any existing or proposed waste management systems which include manure storage structures, transfer and treatment systems, feedlots, confined buildings, and waste storage and treatment systems (IDEM, 2002). Complete manure management plans contain procedures for manure and soil testing, methods for manure application, and agreements with owners where off-site land application will occur. The manure management plan should provide adequate information to determine the theoretical annual volume of manure produced, the capacity required to provide 180 days of manure storage with contingency space for a 24-hour, 25-year rain event, and the acreage required for land application (Purdue Cooperative Extension Agency, 1998).

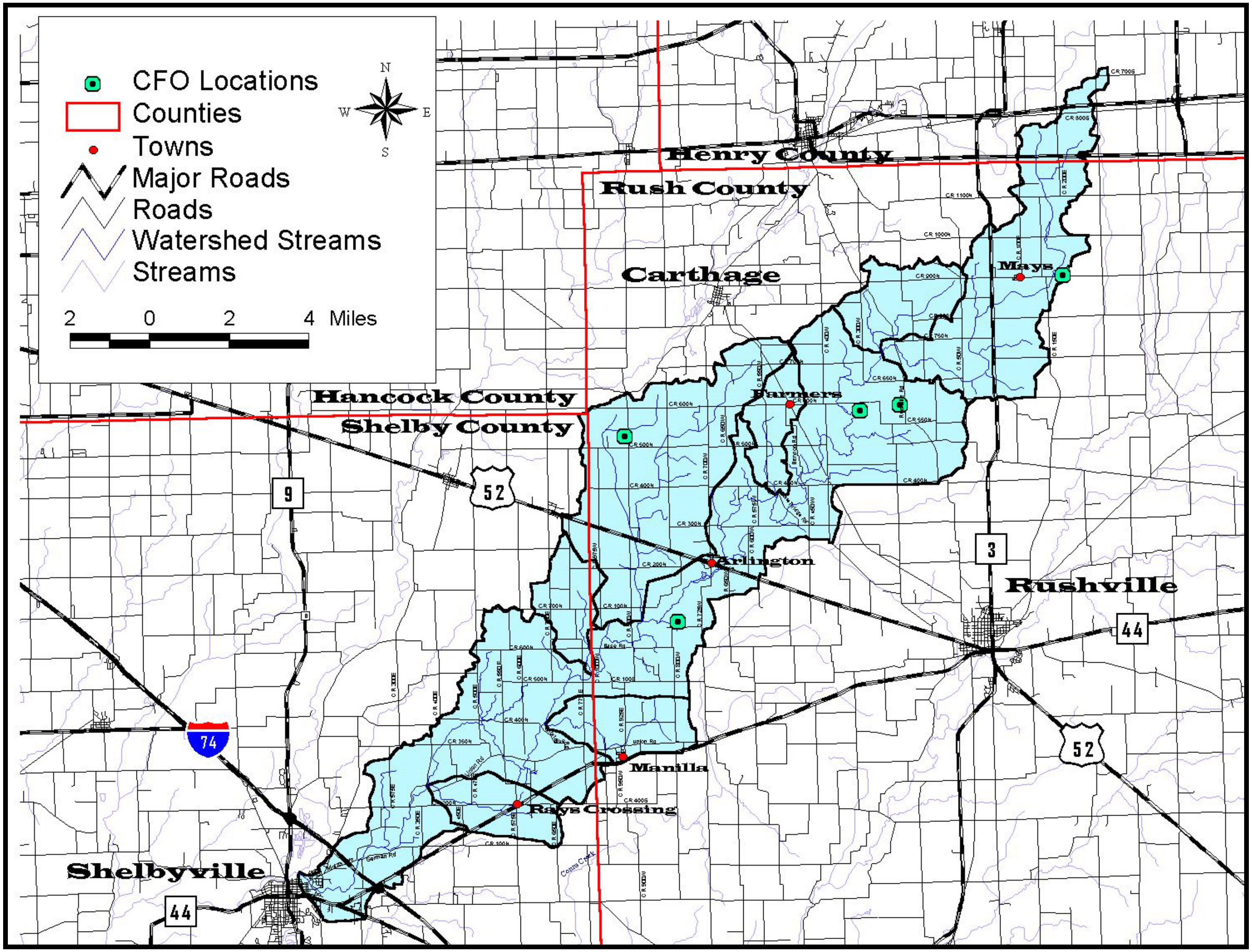


Figure 15. Confined Feeding Operation locations. Source: See Appendix A.

Each type of CFO manages different volumes of manure annually. The total manure volume is determined by the type of animal, the number of animals maintained, and the nutrient and mineral content of animal feed. Table 17 displays the average volume of solid and liquid manure produced by cattle and swine daily and annually. (Because beef cattle and swine are the two types of confined feeding operations present in the Little Blue River Watershed production values for these animals are displayed.)

Table 17. Average daily and annual solid and liquid manure production volumes.

Animal	Daily Solid Manure Production	Daily Liquid Manure Production	Annual Solid Manure Production	Annual Liquid Manure Production
Beef cow				
Feeder Calf	0.32 ft^3/d	0.57 ft^3/d	117.5 ft^3/yr	208.1 ft^3/yr
Fattening Cattle	0.54 ft^3/d	1.14 ft^3/d	197.1 ft^3/yr	416.1 ft^3/yr
Mature Cow	0.59 ft^3/d	1.32 ft^3/d	215.4 ft^3/yr	481.8 ft^3/yr
Swine				
Nursery	0.02 ft^3/d	0.05 ft^3/d	7.3 ft^3/yr	18.25 ft^3/yr
Finishing	0.08 ft^3/d	0.18 ft^3/d	29.2 ft^3/yr	65.7 ft^3/yr
Farrowing	0.21 ft^3/d	0.51 ft^3/d	76.65 ft^3/yr	186.15 ft^3/yr
Breeding	0.09 ft^3/d	0.16 ft^3/d	32.85 ft^3/yr	58.4 ft^3/yr

Source: IDEM, 2002.

All waste including bedding materials, urine, barn wash water, and any runoff that enters storage tanks must be handled as manure and is pumped into manure storage tanks. Each CFO must provide a minimum of 120 days of manure storage. Generally, solid and liquid manure is stored and applied separately. CFO operators base manure application rates on soil-available nitrogen and recommended agronomic nitrogen rates. Prior to April 2002, manure application rates were based on a recommended agronomic nitrogen rate of 150 pounds per acre (Purdue Cooperative Extension Agency, 1998). IDEM initially regulated all of the CFOs in the Little Blue River Watershed at the 150 pounds of nitrogen per acre rate. Using this nitrogen goal, each acre can be supplemented with manure from 9 feeder calves or 5 mature beef cows or 13 farrowing or 25 finishing pigs (Table 18). After April 2002, IDEM required CFO operators to recalculate manure application rates based on the intended cover crop and the available soil nitrogen. Table 19 shows typical plant available nitrogen values utilized for manure application rate calculations following the April 2002 rule change (IDEM, 2002). Recalculated average manure application rates indicate that former application rates (pre-2002) supplied more nitrogen to the soil than the plants could utilize. The practice of over-fertilizing often allows nitrogen and phosphorus to accumulate in the soil. This accumulation can create an imbalance of nutrients resulting in poor plant growth or lead to high levels of nitrogen and phosphorus loading to drainage tiles and surface waters from direct runoff or from soil leaching (Sutton, 1994; Wang et. al, 2002).

Table 18. Animal capacity per acres of land using average manure application rates and acreage requirements for the minimum number of animals. The calculation assumes that the minimum number of animals are maintained (300 beef cattle or 600 swine).

Animal	Animal Capacity (# animals/acre)	Required Acreage to Maintain Minimum Number of Animals
Beef cow		
Feeder calf	9	33.3 acres
Fattening cattle	4	75 acres
Mature cow	5	60 acres
Swine		
Nursery pig	80	7.5 acres
Finishing	17	35.3 acres
Farrowing	13	46.2 acres
Breeding	25	24 acres

Source: Purdue Cooperative Extension Agency, 1998.

Table 19. Typical plant available nitrogen values utilized for manure application rate calculations following April 2002.

Crop	Plant Available Nitrogen Requirements
Corn	150 lb/acre
Soybeans	100 lb/acre
Hay/grass	100 lb/acre
Small grains	100 lb/acre
Set aside	100 lb/acre

Source: IDEM, 2002.

Kopp Land and Livestock operates an IDEM-regulated confined feeding operation located west-northwest of the Town of Occident at 1746 West County Road 550 North (Figure 15). The property drains through a drainage ditch to the Little Blue River. Kopp Land and Livestock is permitted to house 700 beef cattle, which produce approximately 419,600 cubic feet of manure annually (Table 20; IDEM CFO Log #547). Cattle are housed in two units: a 400 beef unit containing an 80,000 cubic feet concrete manure storage pit beneath the slotted floor and a 300 beef unit containing two 14,400 cubic feet open concrete pits for manure storage. A 56,000 cubic feet earthen lagoon provides overflow manure storage and feedlot runoff storage. In total, the four storage facilities provide more than one year's manure storage capacity. Manure is periodically removed from these storage facilities and applied to portions of 520 acres available on adjacent farmland. Kopp Land and Livestock's manure application rates are set to supply 150 pounds of nitrogen per acre because the application was filed prior to April 2002. During the next application renewal cycle Kopp Land and Livestock must recalculate manure application rates based on soil type, plant available nitrogen, and cover crop. IDEM inspectors have not noted any spills or violations during Kopp Land and Livestock's five years of operation (manure management plan approved March 7, 2000).

Table 20. Number and type of beef cattle and average manure production rates for Kopp Land and Livestock.

Animal	Number of Animals Permitted	Average Daily Solid Manure Production	Average Daily Liquid Manure Production	Average Annual Solid Manure Production	Average Annual Liquid Manure Production
Feeder	150	48.0 ft^3/d	85.5 ft^3/d	17,520 ft^3/yr	31,207 ft^3/yr
Fattening	150	81.0 ft^3/d	171.0 ft^3/d	29,565 ft^3/yr	62,415 ft^3/yr
Mature	400	236.0 ft^3/d	528.0 ft^3/d	86,140 ft^3/yr	192,720 ft^3/yr
Totals	**700**	**365.0 ft^3/d**	**784.5 ft^3/d**	**133,225 ft^3/yr**	**286,342 ft^3/yr**

Source: IDEM CFO files, Log #547.

Ronald Sullivan operates an IDEM-regulated confined feeding operation located immediately east of Beaver Meadow Creek at 9140 West County Road 500 North (Figure 15). The property lies adjacent to Beaver Meadow Creek west of Linn Creek. Mr. Sullivan is permitted to house 2,000 hogs which produce approximately 172,625 cubic feet of manure annually (Table 21; IDEM CFO Log #2950). The facility consists of two finishing buildings which house 1,000 hogs each; liquid manure is stored in concrete pits beneath the slotted floors of both facilities. Solid manure and confined feeding area runoff is also stored in these storage units which have a total capacity to store 59,280 cubic feet each. Sullivan's manure application rates are set to supply 150 pounds of nitrogen per acre because the application was filed prior to April 2002. During the next renewal cycle Mr. Sullivan must recalculate manure application rates for the facility based on soil type, plant available nitrogen, and cover crop. IDEM inspectors have not noted any spills or violations during the 9 years of operation at the facility (manure management plan approved September 12, 2000).

Table 21. Number and type of swine and average manure production rates for Ronald Sullivan's farm.

Animal	Number of Animals Permitted	Average Daily Solid Manure Production	Average Daily Liquid Manure Production	Average Annual Solid Manure Production	Average Annual Liquid Manure Production
Nursery	360	7.2 ft^3/d	18.0 ft^3/d	2,628 ft^3/yr	6,570 ft^3/yr
Finishing	1,425	114.0 ft^3/d	256.5 ft^3/d	41,610 ft^3/yr	93,623 ft^3/yr
Farrowing	50	10.5 ft^3/d	25.5 ft^3/d	3,833 ft^3/yr	9,308 ft^3/yr
Breeding	150	13.5 ft^3/d	24.0 ft^3/d	4,928 ft^3/yr	8,760 ft^3/yr
Boars	15	1.4 ft^3/d	2.4 ft^3/d	493 ft^3/yr	876 ft^3/yr
Totals	**2,000**	**146.6 ft^3/d**	**326.4 ft^3/d**	**53,491 ft^3/yr**	**119,136 ft^3/yr**

Source: IDEM CFO files, Log #2950.

Robert Veach operates an IDEM-regulated confined feeding operation located near the intersection of County Road 715 West and County Road 50 North (Figure 15). The property lies adjacent to the Little Blue River immediately upstream of its confluence with Beaver Meadow Creek. Mr. Veach is permitted to house 330 swine on his property which produce a total of 28,400 cubic feet of manure annually (Table 22; IDEM CFO Log #4437). Typically, Mr. Veach's facility would not be included in the Confined Feeding Operation program; however, violations associated with this facility in the past require that any swine housed on the property be regulated as a CFO. In April 1989, the Rush County sanitarian reported swine waste entering a tributary to the Little Blue River. Subsequent inspection reports filed by IDEM Office of Environmental Response personnel indicated that water quality samples collected at the time of the inspection contained pollutant concentrations consistent with pollution levels in water degraded by swine waste discharge. Additionally, inspectors observed swine waste flowing across an adjacent landowner's property, into the tributary, then into the Little Blue River. Following a series of settlement conferences, IDEM required that Mr. Veach remove all swine from the property, clean the confinement area and all buildings, and pay a fine to the state. Any future swine operations housed on this property were then required to file a confined feeding operation application for the facility. Mr. Veach submitted a confined feeding operation application package and was approved to operate a CFO on this property on March 2, 2000. Veach's manure application rates are set to supply 150 pounds of nitrogen per acre because his application was filed prior to April 2002. During the next renewal cycle, Mr. Veach must recalculate manure application rates for the facility based on soil type, plant available nitrogen, and cover crop. IDEM inspectors have not noted any spills or violations since the facility began operating again.

Table 22. Number and type of swine and average manure production rates for Robert Veach's farm.

Animal	Number of Animals Permitted	Average Daily Solid Manure Production	Average Daily Liquid Manure Production	Average Annual Solid Manure Production	Average Annual Liquid Manure Production
Nursery	60	1.2 ft^3/d	3.0 ft^3/d	438 ft^3/yr	1,095 ft^3/yr
Finishing	235	18.8 ft^3/d	42.3 ft^3/d	6,862 ft^3/yr	15,440 ft^3/yr
Farrowing	8	1.7 ft^3/d	4.1 ft^3/d	613 ft^3/yr	1,489 ft^3/yr
Breeding	25	2.3 ft^3/d	4.0 ft^3/d	821 ft^3/yr	1,460 ft^3/yr
Boars	2	0.2 ft^3/d	0.3 ft^3/d	66 ft^3/yr	117 ft^3/yr
Totals	**330**	**24.1 ft^3/d**	**53.7 ft^3/d**	**8,800 ft^3/yr**	**19,601 ft^3/yr**

Source: IDEM CFO files, Log #4437.

William Smith operates an IDEM-regulated confined feeding operation located northwest of the Town of Occident near the intersection of County Road 600 North and County Road 290 West (Figure 15). Mr. Smith is permitted to house 3,800 swine on his property which produce approximately 320,400 cubic feet of manure annually (Table 23; IDEM CFO Log #4909). Periodically, manure is removed from the storage facilities and injected into several hundred acres of adjacent farmland. Smith's manure application rates are set to supply 150 pounds of nitrogen per acre because his application was filed prior to April 2002. During the next renewal cycle, Mr. Smith must recalculate manure application rates for the facility based on soil type, plant available nitrogen, and cover crop. IDEM inspectors noted that the only issue at the facility was that a previous spill site needed to be cleaned more thoroughly and that materials associated with the spill area should be hauled off-site following clean-up.

Table 23. Number and type of swine and average manure production rates for Smith Farm #3.

Animal	Number of Animals Permitted	Average Daily Solid Manure Production	Average Daily Liquid Manure Production	Average Annual Solid Manure Production	Average Annual Liquid Manure Production
Nursery	720	14.4 ft^3/d	36.0 ft^3/d	5,256 ft^3/yr	13,140 ft^3/yr
Finishing	2,690	215.2 ft^3/d	484.2 ft^3/d	78,548 ft^3/yr	176,733 ft^3/yr
Farrowing	65	13.7 ft^3/d	33.2 ft^3/d	4,982 ft^3/yr	12,100 ft^3/yr
Breeding	310	27.9 ft^3/d	49.6 ft^3/d	10,184 ft^3/yr	18,104 ft^3/yr
Boars	15	1.4 ft^3/d	2.4 ft^3/d	493 ft^3/yr	876 ft^3/yr
Totals	**3,800**	**272.5 ft^3/d**	**605.4 ft^3/d**	**99,463 ft^3/yr**	**220,953 ft^3/yr**

Source: IDEM CFO files, Log #4909.

Philip White operates an IDEM-regulated confined feeding operation located east of the Town of Mays at 2482 East County Road 900 North (Figure 15). The property lies adjacent to the Little Blue River on its east bank. Mr. White is permitted to house 1,475 swine on his property, which, in turn, produce approximately 124,300 cubic feet of manure annually (Table 24; IDEM CFO Log #1935). Lagoons are not utilized for manure storage at this facility; manure is stored beneath the swine barns. Periodically, manure is removed and injected into approximately 700 acres. White's manure application rates are set to supply 150 pounds of nitrogen per acre because his application was filed prior to April 2002. During the next renewal cycle, Mr. White must recalculate manure application rates for the facility based on soil type, plant available nitrogen, and cover crop. IDEM inspectors have not noted any spills or violations during the 27 years of operation (manure management plan approved August 2001). The only issue noted during an April 1999 inspection was that rain water should be diverted away from the swine barn and the manure storage area.

Table 24. Number and type of swine and average manure production rates for Philip White's farm.

Animal	Number of Animals Permitted	Average Daily Solid Manure Production	Average Daily Liquid Manure Production	Average Annual Solid Manure Production	Average Annual Liquid Manure Production
Nursery	280	5.6 ft^3/d	14.0 ft^3/d	2,044 ft^3/yr	5,110 ft^3/yr
Finishing	1,045	83.6 ft^3/d	188.1 ft^3/d	30,514 ft^3/yr	68,657 ft^3/yr
Farrowing	25	5.3 ft^3/d	12.8 ft^3/d	1,916 ft^3/yr	4,654 ft^3/yr
Breeding	120	10.8 ft^3/d	19.2 ft^3/d	3,942 ft^3/yr	7,008 ft^3/yr
Boars	5	0.5 ft^3/d	0.8 ft^3/d	164 ft^3/yr	292 ft^3/yr
Totals	**1,475**	**105.7 ft^3/d**	**234.9 ft^3/d**	**38,581 ft^3/yr**	**85,720 ft^3/yr**

Source: IDEM CFO files, Log #1935.

2.6.2 Non-agricultural Land Use in the Little Blue River Watershed

Aside from agricultural uses, forests and wetlands represent the other notable land use within the study watershed (Figure 11). In many cases along the mainstem of the Little Blue River, these forested and wetland natural areas directly border stream segments. Not only do these forest areas and wetlands help moderate stream water temperature and velocity, they also offer water storage capacity and sediment and nutrient filtration. Figure 16 further classifies the wetlands based on National Wetland Inventory (NWI) data. According to the NWI data, most wet areas are palustrine, forested wetlands (Table 25). Due to the small remaining concentration of forest and wetland land use (only about 5% of the watershed), their protection is merited. Farmers should also be encouraged to route drainage tiles toward specified treatment wetlands or filter areas. Riparian buffer area filtration is drastically reduced when drainage tiles completely bypass them, carrying drainage water directly to the ditch.

Table 25. National Wetland Inventory (NWI) data for the Little Blue River Watershed.

Wetland Type	Area (acres)	Area (hectares)
Palustrine forested	931.4	377.1
Palustrine emergent	119.2	48.2
Ponds	82.1	33.2
Palustrine scrub/shrub	25.5	10.3
Lacustrine	11.2	4.5
Uplands	66,313.1	26,847.4

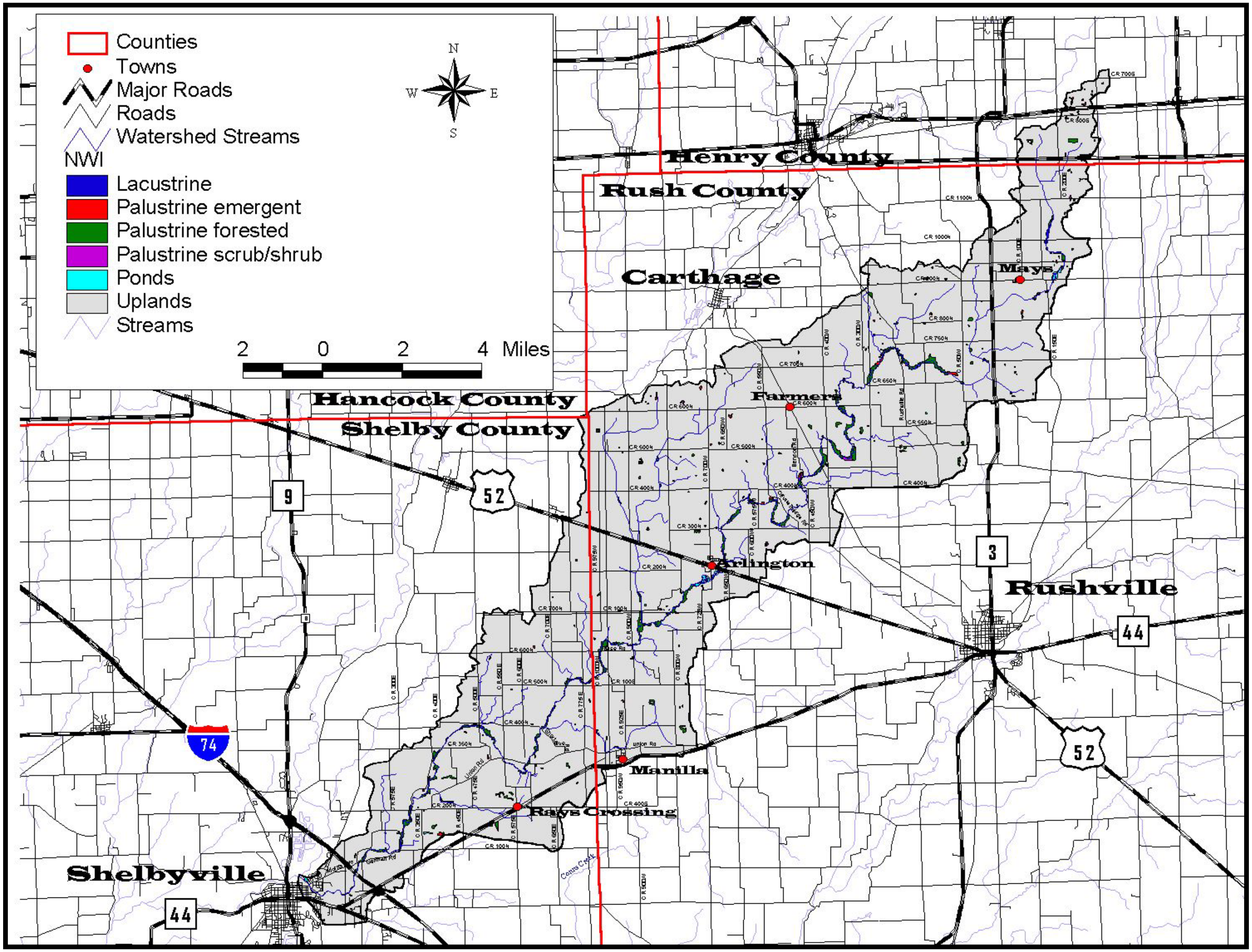


Figure 16. National Wetland Inventory (NWI) map. Source: See Appendix A.

Other land uses are very negligible within the Little Blue River Watershed. Urban areas including both residential and commercial land use occupy 1.2% of the watershed. The remaining land uses and coverage compose a meager 0.3% of the watershed. These include non-vegetated developed land, recreation or park land, and open water.

2.6.3 Subwatershed Land Use

In general, row crop agriculture dominates land use throughout the subwatersheds (Figure 17). The Rays Crossing Tributary Subwatershed is the most diverse tributary subwatersheds with respect to different types of land use, while the Little Gilson Creek, Cotton Run, and Farmers Stream Subwatersheds are the least diverse. The Lower Middle Blue, Manilla Branch, and Middle Little Blue Subwatersheds are the only subwatersheds that contain any notable acreages of urban land due to the towns of Shelbyville, Manilla, and Arlington.

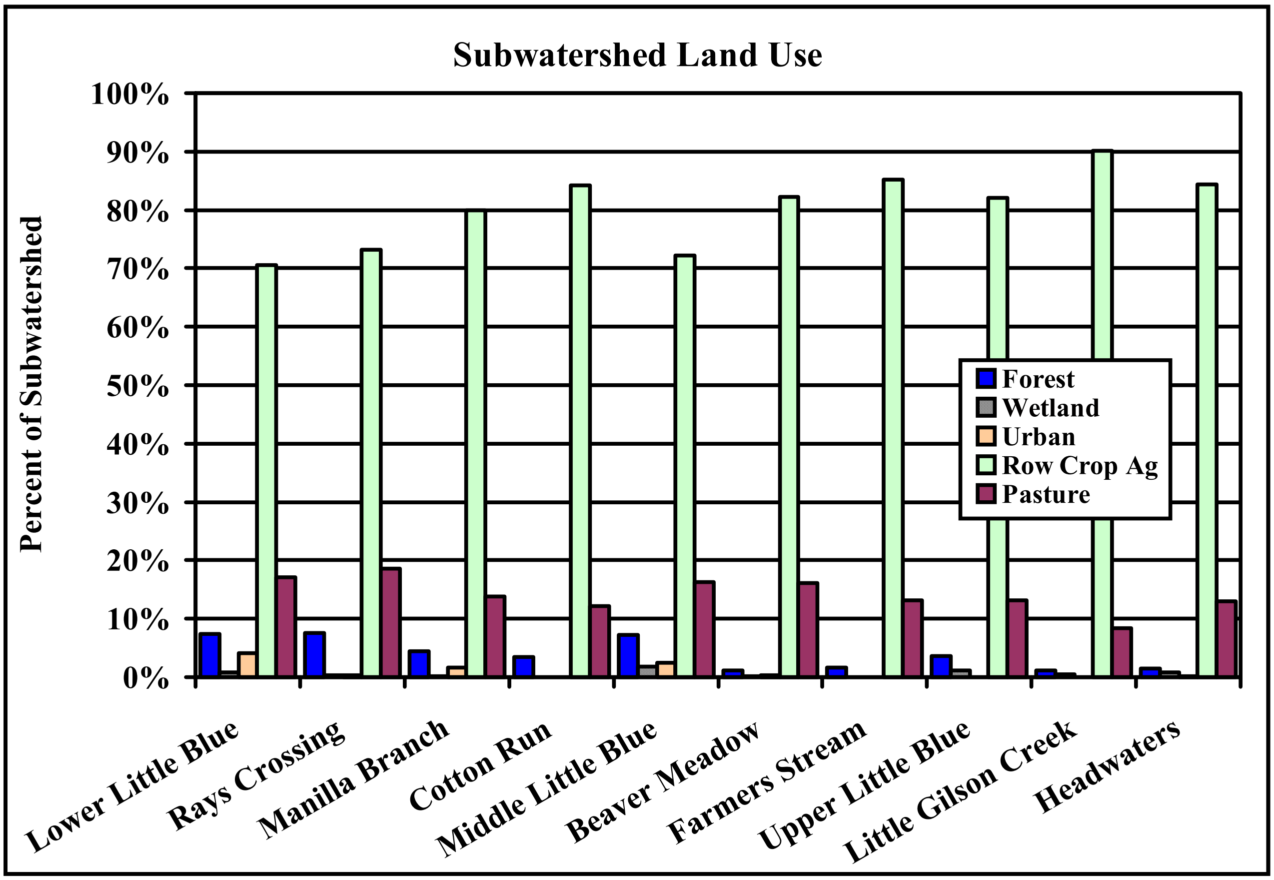


Figure 17. Percent of total watershed area used for the broad land use categories: pasture agriculture, row crop agriculture, urban, wetland, and forest.

Many tracts of pastureland directly border streams in the watershed (Figure 11). The Rays Crossing Tributary, Beaver Meadow Creek, Farmers Stream, and Headwaters Subwatersheds contain some pastureland tracts that border the Little Blue River tributaries. When pastured livestock is allowed direct access to streams, pastureland use is closely coupled with riparian area degradation and increased soil, nutrient, and bacterial runoff. Efforts should be made to exclude livestock from waterways in these critical areas.

3.0 HISTORICAL GEOCHEMICAL STUDIES

3.1 HISTORICAL GROUNDWATER CHEMISTRY STUDIES

3.1.1 Nitrate Leaching Study

Purdue University professor Bernie Engel created the Nitrate Leaching and Economic Analysis Package (NLEAP). The model combines a nitrogen budget with water balance to calculate the amount of nitrate-nitrogen leached below the root zone. The model generates an annual leaching risk potential (ALRP) score that can be used to qualitatively assess the affects of nitrate-nitrogen leaching. ALRP scores fall into seven categories: areas with scores of 1-4 are considered very low risk of nitrate-nitrogen leaching; scores of 5-8 are considered low risk; scores of 9-16 are moderate risk; 17-32 are high risk; scores of 33-64 are considered very high risk; scores of 65-128 are extreme risk; and areas with scores of 129-256 are considered at very extreme risk for nitrate-nitrogen leaching.

Figure 18 displays the five broad nitrate-nitrogen leaching risk potential categories as calculated by the NLEAP model for the Little Blue River Watershed. No areas of extreme or very extreme risk were calculated for the Little Blue River Watershed. Much of the watershed is considered at moderate to high risk for nitrate-nitrogen leaching. Areas at the northeast edge of Shelbyville are at the greatest risk for nitrate-nitrogen leaching, while the headwaters area near the intersection of State Road 3 and State Road 40 has very low risk for nitrate-nitrogen leaching potential. Another large section of the watershed containing the Farmers Stream Subwatershed and the headwaters of Linn Creek is also at low risk for nitrate-nitrogen leaching.

3.1.2 Pesticide Leaching Study

Engel has also assisted in the development of the National Agricultural Pesticide Risk Analysis (NAPRA) process for the state of Indiana. The NAPRA web model allows individuals to generate and evaluate management alternatives for farm fields, sections, counties, or regions. Once individuals submit data for their respective fields, it is integrated into the statewide system which will be used to assess statewide management strategies. Through the development of this system, modeling by Purdue University professor Bernie Engel, showed that 75% of detectable pesticides in groundwater came from 25% of farmland. Using his data, Dr. Engel helped the State write the Indiana State Pesticide Management Plan (available on-line at http://www.isco.purdue.edu/psmp/oiscmain.htm). Engel initiated a model program similar to the NLEAP system developed for nitrate-nitrogen leaching potential which calculates pesticide leaching risk potential. The pesticide model generates only three categories: low risk, moderate risk, and high risk.

Much of the Little Blue River Watershed is at low risk for pesticide leaching (Figure 19). The mainstem of the Little Blue River from southeast of Arlington to the northwest edge of Shelbyville, a portion of the headwaters of the Little Blue River, and much of the area lying between Beaver Meadow Creek and Linn Creek are at moderate risk for pesticide leaching. High risk areas are located with Shelbyville near the confluence with the Big Blue River and in the headwaters east of State Road 3. Given the high risk of pesticide leaching in the northern portion of the Little Blue River Watershed, weed and pest management is of particular importance. Moderately high risk of pesticide leaching also makes weed and pest management important in the lower portion of the watershed.

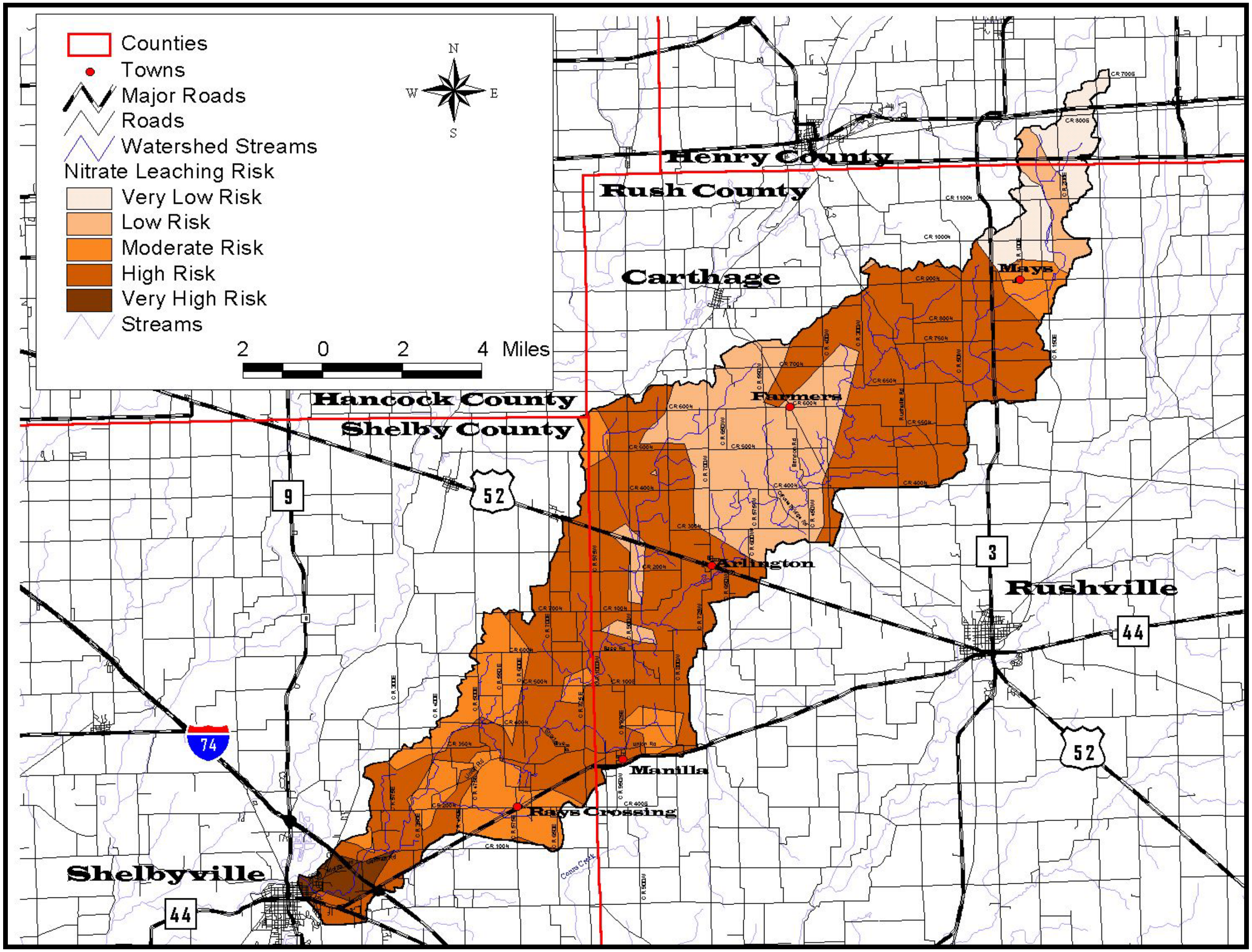


Figure 18. Nitrate leaching risk map.

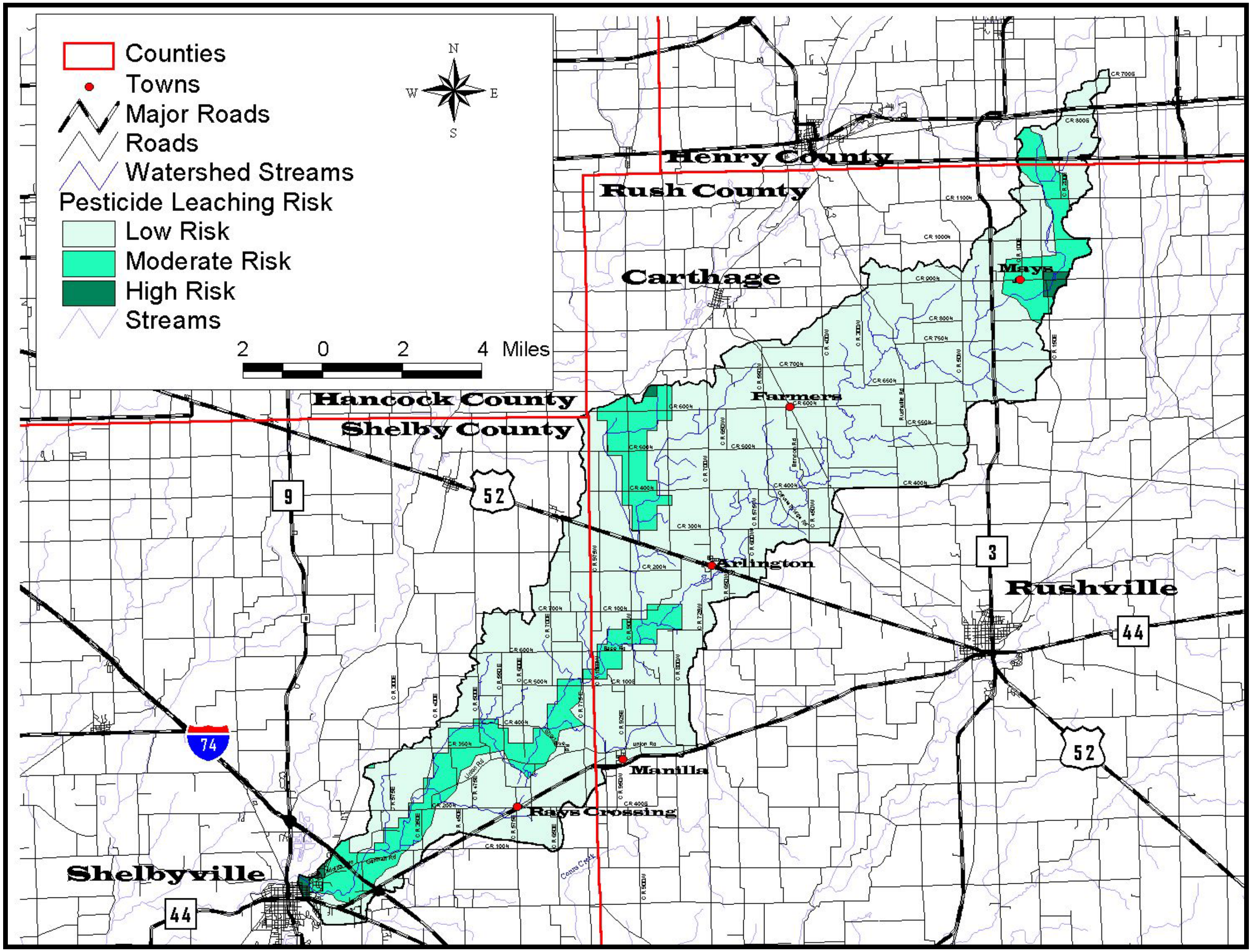


Figure 19. Pesticide leaching risk map.

3.1.3 Cooperative Private Well Testing Program Study

A surface waterbody's groundwater watershed is that area below the ground that drains to the surface waterbody. Typically, a waterbody's groundwater watershed and its surface water watershed boundaries do not correspond exactly. Due to the complicated modeling involved with groundwater watershed boundary determinations, determining the boundary of the Little Blue River groundwater watershed was not included in this study. Nonetheless, the chemical constituents present in the groundwater aquifer can eventually reach surface waterbodies. Therefore, the results of groundwater samples collected throughout Shelby and Rush Counties through the Cooperative Private Well Testing Program directed by Heidelberg College are included in this discussion. (Please note that it is likely that not all of the samples were collected from within the Little Blue River groundwater watershed.) Henry County has not participated in the Cooperative Private Well Testing Program.

The Heidelberg College water quality testing laboratory located in Tiffin, Ohio coordinates the nationwide Cooperative Private Well Testing Program (CPWTP). Through this program, individuals can have drinking water well water samples analyzed for a wide variety of constituents including: nitrates, pesticides, metals, and volatile organic compounds (Heidelberg College, 2002). Several landowners in both Shelby and Rush Counties have taken advantage of this program. Specific tests completed on the Shelby and Rush County samples included nitrate-nitrogen, nitrite-nitrogen, ammonia-nitrogen, chloride, sulfate, conductivity, soluble reactive phosphorus (SRP), and silicon dioxide. Additionally, the laboratory conducted three organic compound screens. The three screens are the Pesticide Immunoassay Screen, which is a highly sensitive, low cost technique for identifying the presence of various groups of pesticides in a water sample, the Lasso/Dual/Acetochlor screen (ALASCR) which indicates concentrations of alachlor containing pesticides, such as Lasso, Dual, or Harness, and the triazine screen (TRISCR) which indicates the presence of common triazine herbicides including AAtrex, Blades, and Princep.

Neither the state of Indiana nor the EPA has established private drinking water well standards. However, the EPA has established public drinking water standards. National Primary Drinking Water Regulations (NPDWR), or primary standards, are legally enforceable standards that apply to public drinking water supplies. Primary standards limit the levels of contaminants in public drinking water systems, thereby protecting public health (USEPA, 2002). Table 26 contains the national maximum contamination level (MCL) drinking water standards for parameters analyzed in the samples collected in Shelby and Rush Counties through the CPWTP.

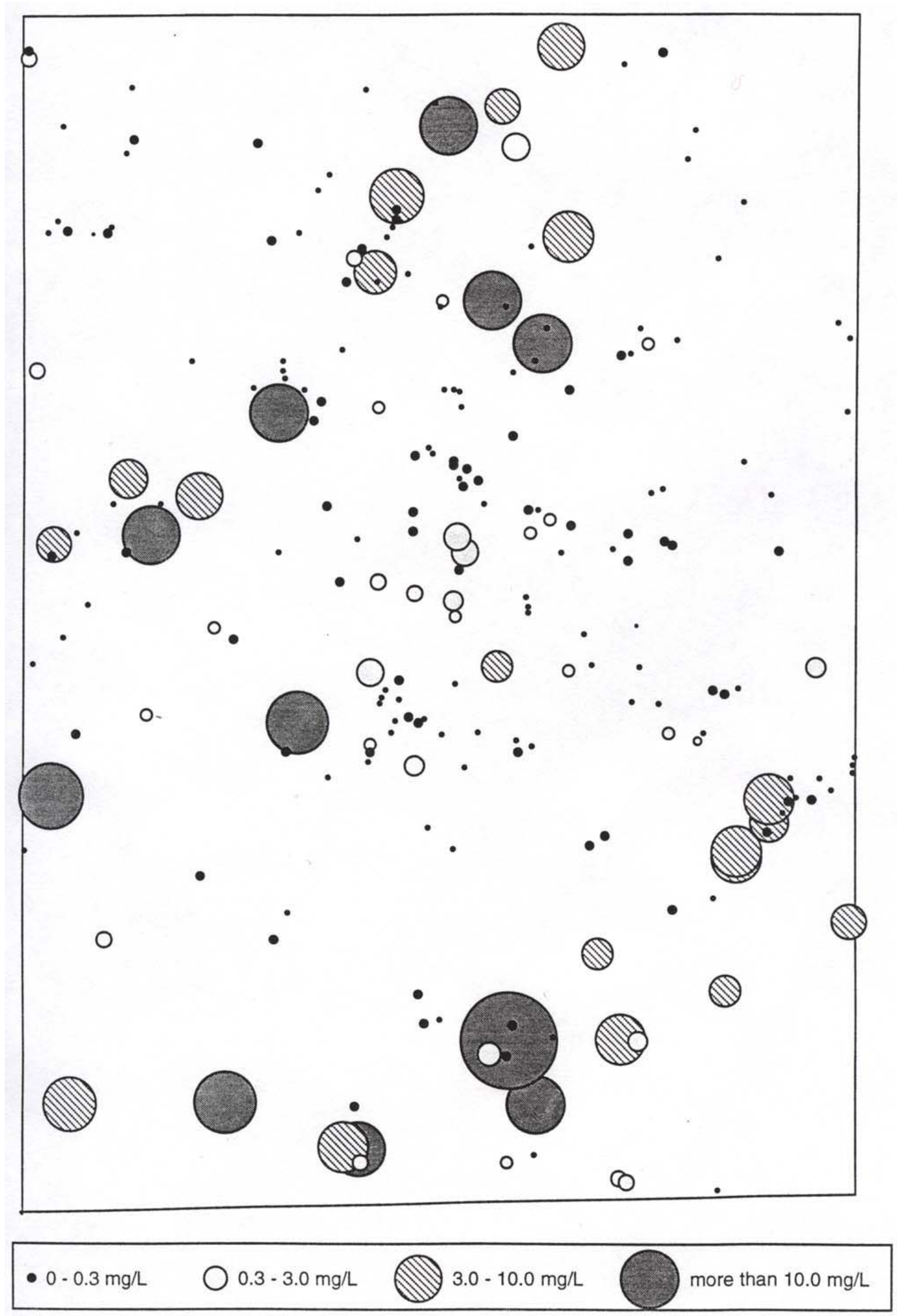
Table 26. National maximum contamination level (MCL) drinking water standards for public drinking water systems.

Parameter	Recommended Standard
Nitrate-Nitrogen (NO_3^--N as N) + Nitrite-Nitrogen (NO_2^--N as N)	1 mg/l
Nitrate-Nitrogen (NO_3^--N as N)	10 mg/l
Ammonia-Nitrogen (NH_3-N as N)	35 mg/l*
Chloride (Cl as Cl_2)	4 mg/l
Sulfate (SO_4^{2-})	400 mg/l
Conductivity	1200 µmos/cm
Silica	--
Phosphorus	--
ALASCR	
Alachlor	0.002 mg/l
Acetochlor	--
Metolachlor	--
TRISCR	
Atrazine	0.003 mg/l
Cyanazine	--
Simazine	0.004 mg/l

Sources: National Academy of Sciences, 1972; USEPA, 1989; OAC, 1996.
*Values this high rarely occur in groundwater. Heidelberg College suggests having groundwater samples tested for bacteria if the ammonia-nitrogen concentration exceeds 0.5 mg/l.

Shelby County CPWTP Results

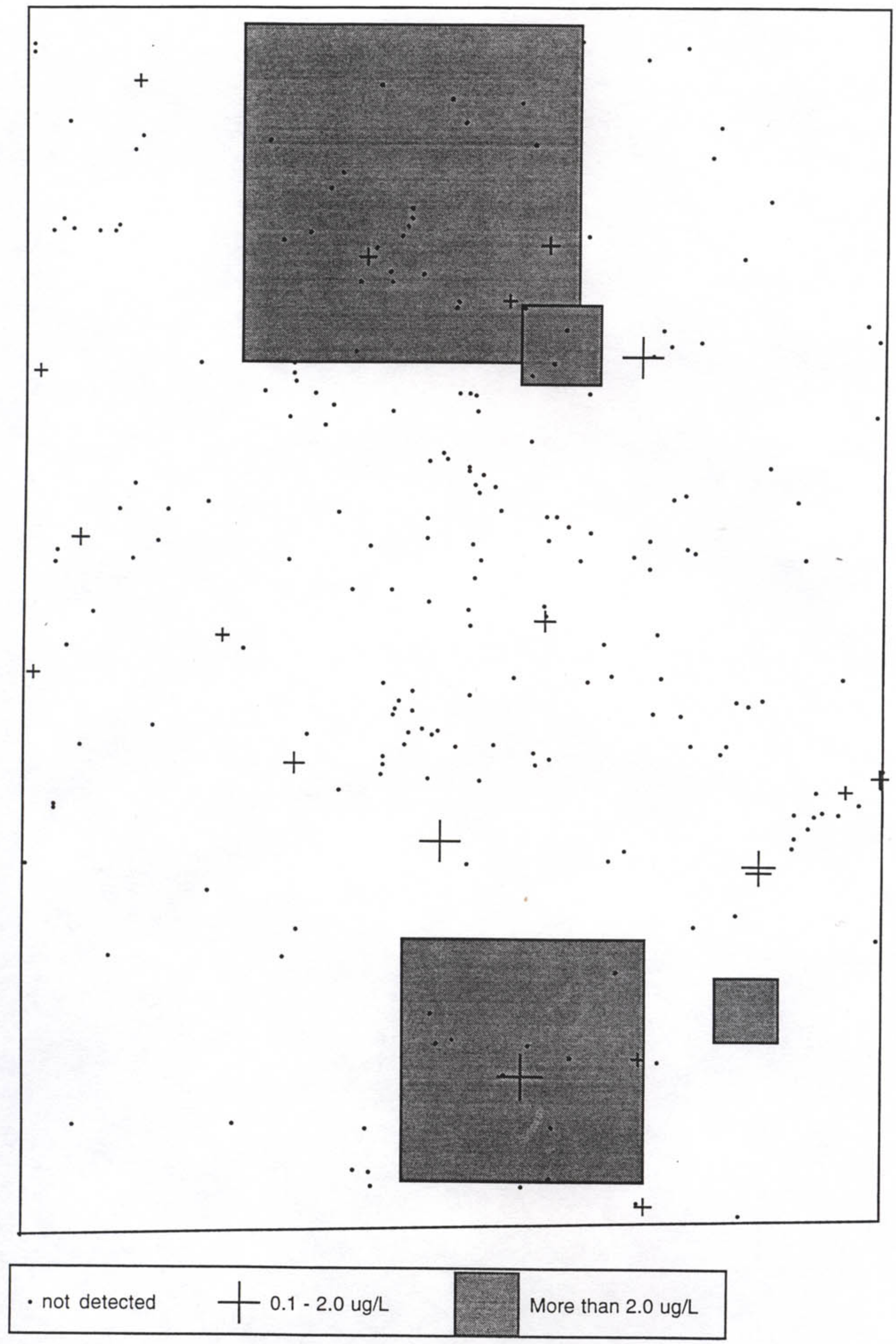
The Cooperative Private Well Testing Program analyzed samples from over 300 wells in Shelby County during the summer of 1991 and the fall and winter 1992 (CPWTP Database, 2003). (Data collected during these sampling periods is contained in Appendix C.) Nitrite-nitrogen concentrations were low in most samples collected during the sampling period; concentrations measured in two of the samples exceeded the national standard (1 mg/l; Appendix C: Table 1). Nitrate-nitrogen concentrations in the samples were below the national standard (10 mg/l) in all but twenty of the collected samples; nitrate-nitrogen concentrations in samples exceeding the standard ranged from 10.49 mg/l to 31.67 mg/l. Figure 20 shows the relative concentrations of nitrate-nitrogen in all of the 305 samples. Samples containing high nitrate-nitrogen concentrations were almost evenly distributed throughout the county with the exception of the Shelbyville area, which does not appear to house any tested wells in violation of the standard. Although there is moderate to high nitrate leaching risk within the Little Blue River surface watershed (Figure 18) nitrate-nitrogen does not appear to be reaching groundwater wells throughout most of the watershed (Figure 20). None of the sampled wells possessed ammonia-nitrogen concentrations in excess of the 35 mg/l standard; however, 27 samples contained ammonia-nitrogen concentrations greater than 0.5 mg/l indicating that bacteria may be present in many wells throughout Shelby County. Chloride concentrations exceeded the national standard in 62% of the samples; concentrations ranged from 0.6 mg/l to 271 mg/l (median concentration 6.3 mg/l).



Source: Indiana Farm Bureau

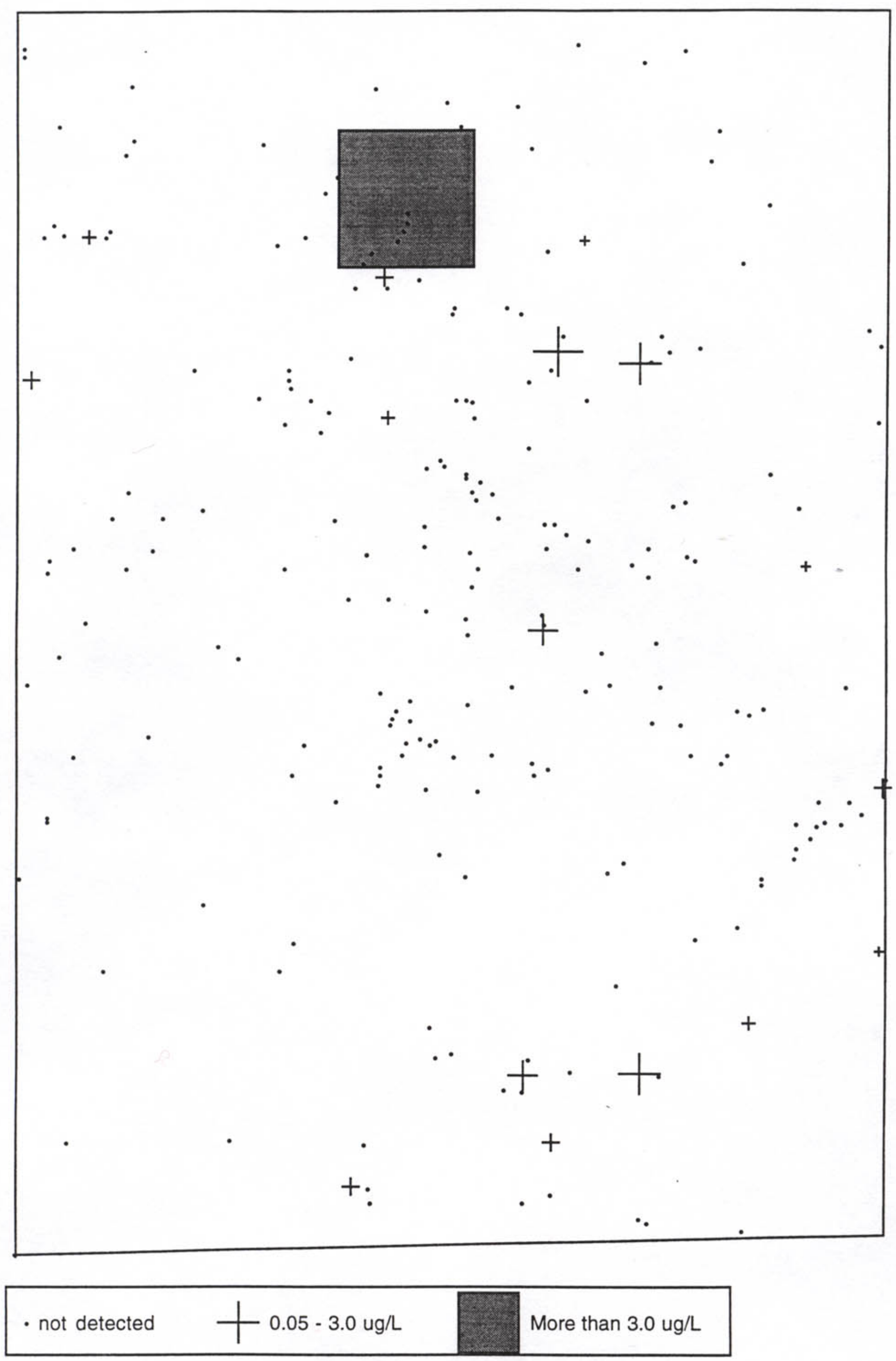
Figure 20. Relative nitrate-nitrogen concentration detected in groundwater well samples collected throughout Shelby County from 1991 to 1992. Exact sample locations are not specified, but individual dots are centered on sample points. The relative size of each dot is indicative of the concentration of nitrate-nitrogen in that sample. Note: neither the surface watershed nor the groundwater watershed is indicated on the map due to scaling and accuracy inconsistencies.

Organic compound screening (ALASCR and TRISCR) was conducted on all of the 305 samples and indicated the presence of pesticides or herbicides in the all of the drinking water well samples. Figures 21 and 22 display relative distributions for both the alachlor screen (ALASCR or Lasso/Dual) and the triazine screen (TRISCR). The screens indicate that a median concentration of 0.03 mg/l of organic, alachlor-containing compounds and 0.01 mg/l of organic, triazine-containing compounds were present in the well samples. ALASCR and TRISCR concentrations ranged from 0.0 mg/l to 73.38 mg/l and 0.01 mg/l to 62.83 mg/l, respectively. Most of the samples containing high pesticide and herbicide concentrations were evenly distributed throughout Shelby County (Figure 1). Based on Figures 21 and 22 provided by the CPWTP and the pesticide leaching risk map, there appears to be moderate risk of pesticide leaching risk along the lower portion of the mainstem of the Little Blue River and low pesticide leaching risk within the remainder of the Little Blue River surface watershed (Figure 19); based on the CPWTP sampling results pesticides do not appear to be reaching groundwater wells throughout most of the watershed located within Shelby County (Figures 21 and 22). Nonetheless, because pesticides are not normally present in private well samples collected in most areas, concentrations measured throughout Shelby County are of concern (Heidelberg College, 2002).



Source: Indiana Farm Bureau

Figure 21. Relative alachlor-containing compound concentration detected in groundwater well samples collected throughout Shelby County from 1991 to 1992. Exact sample locations are not specified, but individual dots are centered on sample points. The relative size of each dot is indicative of the concentration of alachlor-containing compounds in that sample. Note: neither the surface watershed nor the groundwater watershed is indicated on the map due to scaling and accuracy inconsistencies.

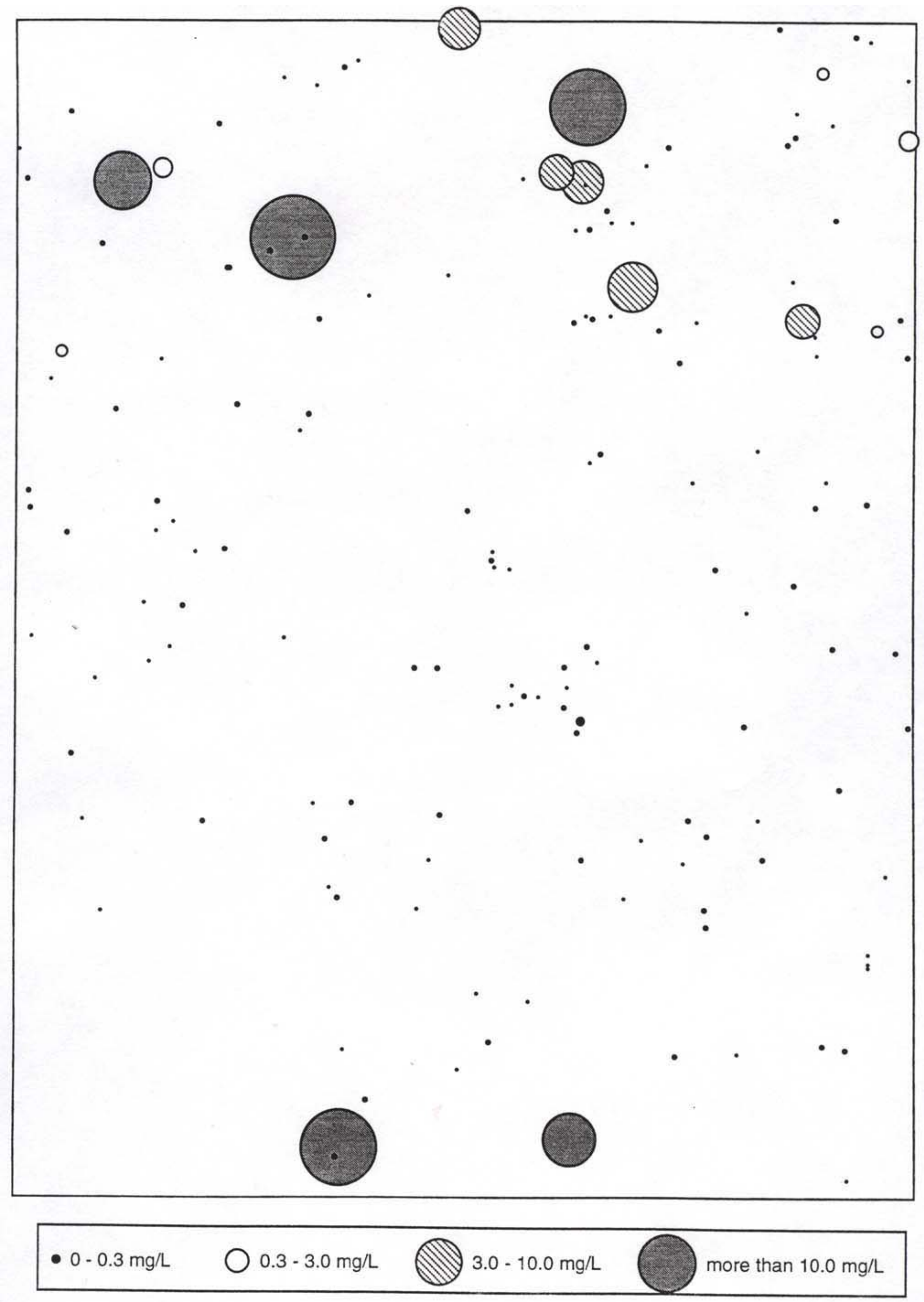


Source: Indiana Farm Bureau

Figure 22. Relative triazine-containing compound concentration detected in groundwater well samples collected throughout Shelby County from 1991 to 1992. Exact sample locations are not specified, but individual dots are centered on sample points. The relative size of each dot is indicative of the concentration of triazine-containing compounds in that sample. Note: neither the surface watershed nor the groundwater watershed is indicated on the map due to scaling and accuracy inconsistencies.

Rush County CPWTP Results

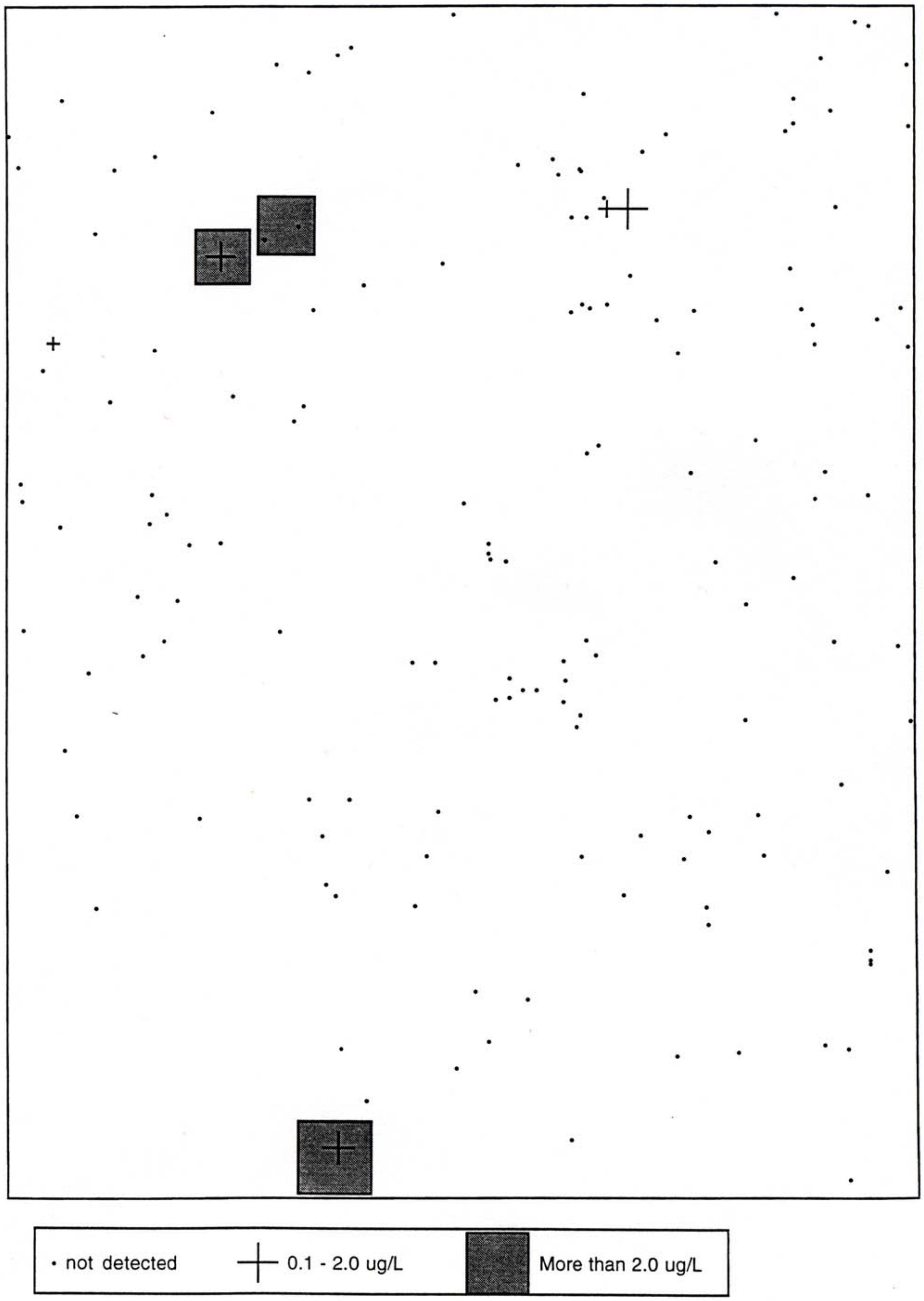
The Cooperative Private Well Testing Program conducted two rounds of sample analysis in Rush County (CPWTP Database, 2003). The first set of samples were collected from 160 wells throughout the county and analyzed during the summer of 1993; the second sampling period occurred during the late summer to early fall of 1999 and included nearly 100 wells in Rush County. (Data collected during these sampling periods is contained in Appendix C.) Nitrite-nitrogen concentrations were low in all samples collected during 1993; concentrations measured in four of the 1999 samples exceeded the national standard (1 mg/l; Appendix C: Tables 2 and 3). In 1993, nitrate-nitrogen concentrations in the samples were below the national standard (10 mg/l) in all but five of the collected samples; nitrate-nitrogen concentrations in samples exceeding the standard ranged from 10.24 mg/l to 23.95 mg/l. None of the samples collected during the 1999 sampling exceeded the national standard. Figure 23 shows the relative concentrations of nitrate-nitrogen in the all samples collected during 1993. (CPWTP did not generate relative concentration maps for the 1999 samples therefore only 1993 sample maps are displayed.) A majority of the samples containing high nitrate-nitrogen concentrations were located along the northern edge of Rush County between Carthage and Raleigh (Figure 1). Although there is very low to high nitrate leaching risk within the Little Blue River surface watershed within Rush County (Figure 18), nitrate-nitrogen does not appear to be reaching groundwater wells throughout most of the watershed located within Rush County (Figure 23). However, nitrate-nitrogen concentrations in groundwater may be an issue near the headwaters of the Little Blue River in Center Township. None of the 1993 or 1999 samples possessed ammonia-nitrogen concentrations in excess of the 35 mg/l standard; however, 57 of the samples collected during 1993 and 32 samples collected in 1999 contained ammonia-nitrogen concentrations greater than 0.5 mg/l. This indicates that bacteria may have been present within many wells throughout Rush County. Chloride concentrations exceeded the national standard in 52% of the 1993 samples and 69% of the 1999 samples. Chloride concentrations ranged from 1 mg/l to 157 mg/l (median concentration 10.45 mg/l) and 1.6 mg/l to 63 mg/l in 1993 and 1999, respectively (median concentration 11.96 mg/l).



Source: Indiana Farm Bureau

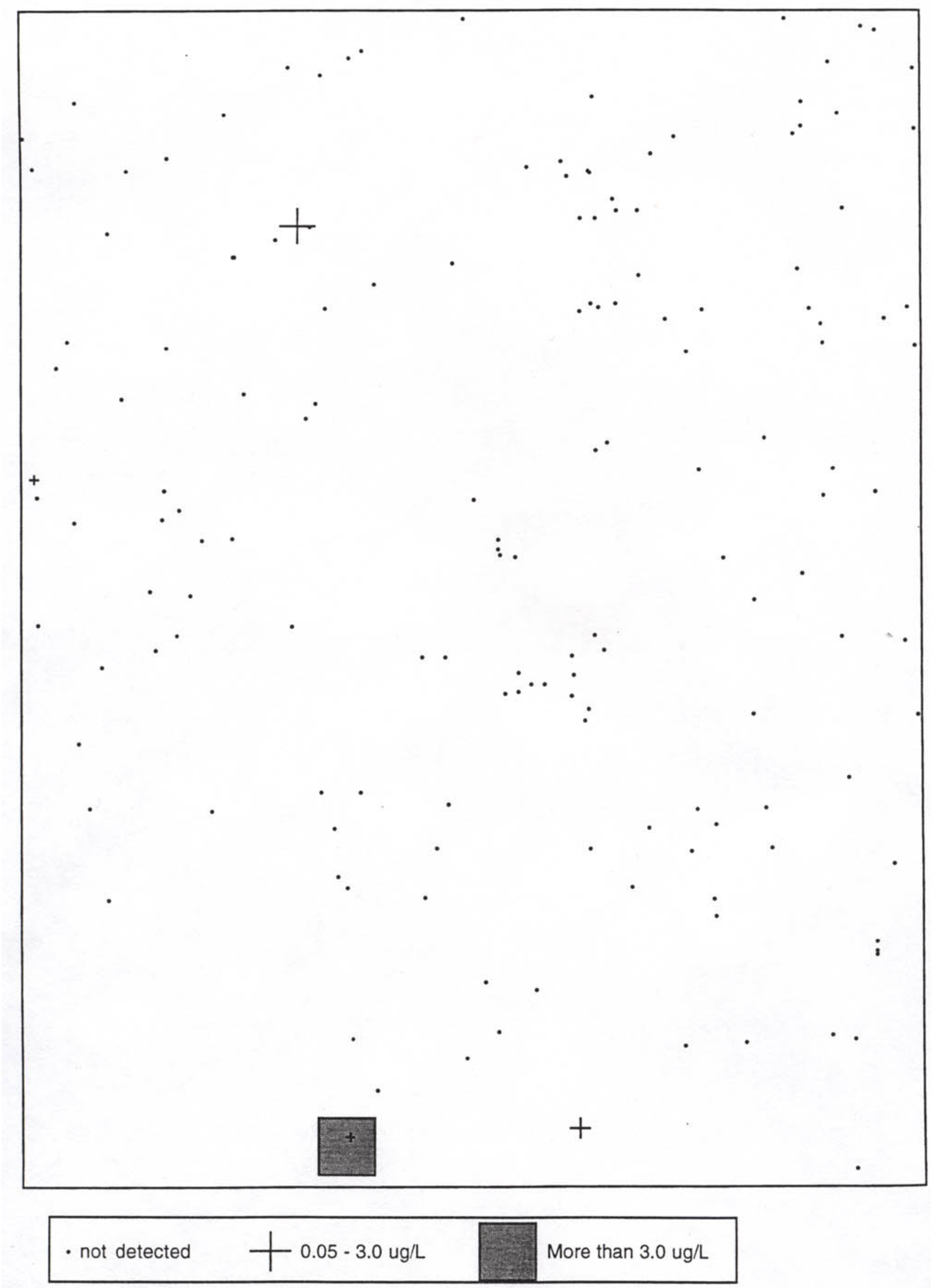
Figure 23. Relative nitrate-nitrogen concentration detected in groundwater well samples collected throughout Rush County in 1993. Exact sample locations are not specified, but individual dots are centered on sample points. The relative size of each dot is indicative of the concentration of nitrate-nitrogen in that sample. Note: neither the surface watershed nor the groundwater watershed is indicated on the map due to scaling and accuracy inconsistencies.

Organic compound screening (ALASCR and TRISCR) was conducted on all of the 259 samples and indicated the presence of pesticides or herbicides in all but four of the drinking water well samples. Figures 24 and 25 display relative distributions for both the alachlor screen (ALASCR or Lasso/Dual) and the triazine screen (TRISCR) for 1993 samples. (CPWTP did not generate relative concentration maps for the 1999 samples therefore only 1993 sample maps are displayed.) The screens indicate that a median concentration of 0.02 mg/l of organic, alachlor-containing compounds and 0.01 mg/l of organic, triazine-containing compounds were present in the well samples collected in 1993. Data from the 1999 samples indicate that median concentration of alachlor-containing compounds was 0.02 mg/l, while the median concentration of 0.02 mg/l of triazine-containing compounds was present. ALASCR and TRISCR concentrations ranged from 0.01 mg/l to 3.03 mg/l and 0.01 mg/l to 3.38 mg/l, respectively in 1993 and from 0 mg/l to 0.18 mg/l and 0.01 mg/l to 0.200 mg/l, respectively in 1999. A majority of the samples containing high pesticide and herbicide concentrations were located in the northern portion of Rush County between Carthage and Raleigh (Figure 1). There is generally a low pesticide leaching risk within the Little Blue River surface watershed (Figure 19); based on CTWTP sampling results pesticides do not appear to be reaching groundwater wells throughout most of the watershed (Figures 24 and 25). Nonetheless, because pesticides are not normally present in private well samples collected in most areas, concentrations measured throughout Rush County are of concern (Heidelberg College, 2002).



Source: Indiana Farm Bureau

Figure 24. Relative alachlor-containing compound concentration detected in groundwater well samples collected throughout Rush County in 1993. Exact sample locations are not specified, but individual dots are centered on sample points. The relative size of each dot is indicative of the concentration of alachlor-containing compound concentration in that sample. Note: neither the surface watershed nor the groundwater watershed is indicated on the map due to scaling and accuracy inconsistencies.



Source: Indiana Farm Bureau

Figure 25. Relative triazine-containing compound concentration detected in groundwater well samples collected throughout Rush County in 1993. Exact sample locations are not specified, but individual dots are centered on sample points. The relative size of each dot is indicative of the concentration of nitrate-nitrogen in that sample. Note: neither the surface watershed nor the groundwater watershed is indicated on the map due to scaling and accuracy inconsistencies

3.2 HISTORICAL STREAM CHEMISTRY STUDIES

Stream chemistry studies have been conducted in the Little Blue River Watershed by the Rush County Health Department (RCHD), Indiana Department of Environmental Management Office of Water Quality, Indiana Department of Natural Resources Division of Fish and Wildlife, Hoosier Riverwatch, and the Indiana State Board of Health. The Rush County Health Department collected twelve *E. coli* samples from drainage tiles, which connect to the Little Blue River from 1991 to 2002 (Figure 26). IDEM assessed water chemistry in the Little Blue River and its tributaries at four sites in 1993, at one site in 1997, and at seven sites in 2002 (Figure 26). The DNR collected four chemical parameters at four sites along the Little Blue River in conjunction with a fisheries survey in 1995 (Figure 26). Hoosier Riverwatch volunteers sampled the Little Blue River immediately north of its confluence with the Big Blue River from 2000 to 2002 (Figure 26). The Indiana State Board of Health collected water samples from one site on the Little Blue River in conjunction with fisheries and macroinvertebrate community surveys in 1964 (Figure 26). Water quality data collected in the Big Blue River Watershed are included in Appendix D. (Please see the Water Chemistry Methods Section for a more detailed description of water quality parameters.)

3.2.1 Rush County Health Department Study

The RCHD sampled twelve privately and county maintained drainage tiles near the towns of Arlington and Manilla from 1991 to 2002 (Figure 26). According to Table 27, *E. coli* concentrations in the tiles ranged from 490 to 8,700,000 colonies/100 ml. Concentrations exceeded the state standard of 235 colonies/100 ml at all twelve sites. The Western Rush County Sewer District (WRCSD) now treats wastewater from residences within Arlington; the Town of Manilla is slated to hook into the WRCSD system by 2005.

Table 27. Rush County Health Department *E. coli* data collected in the vicinity of Arlington and Manilla from 1991 to 2002.

Site	Date	*E. coli* (col/100 ml)
Tile to Little Blue River upstream of US 52	2/22/1991	530,000
Park Street, Arlington	6/18/1991	280,000
County Road 700 West, Arlington	7/29/1991	49,000
Railroad Tracks Tile to the Little Blue River, Arlington	2/25/1991	670,000
Drainage tile South of US 52	8/16/1993	91,000
County tile at Arlington Pike	8/20/1993	150,000
County tile at Arlington Pike (Short Street)	8/20/1993	8,700,000
County tile at CR 250 South and 975 West	8/29/1994	2,400,000
Ditch at tile outlet on County Road 715 West	4/10/1996	620,000
Rivercrest Drive, Manilla	4/8/2002	1,100
Private tile to the Little Blue River, Manilla	4/8/2002	490
Private tile to the Little Blue River, Manilla	4/8/2002	2,400

Source: Ryan Cassidy, Rush County Health Department

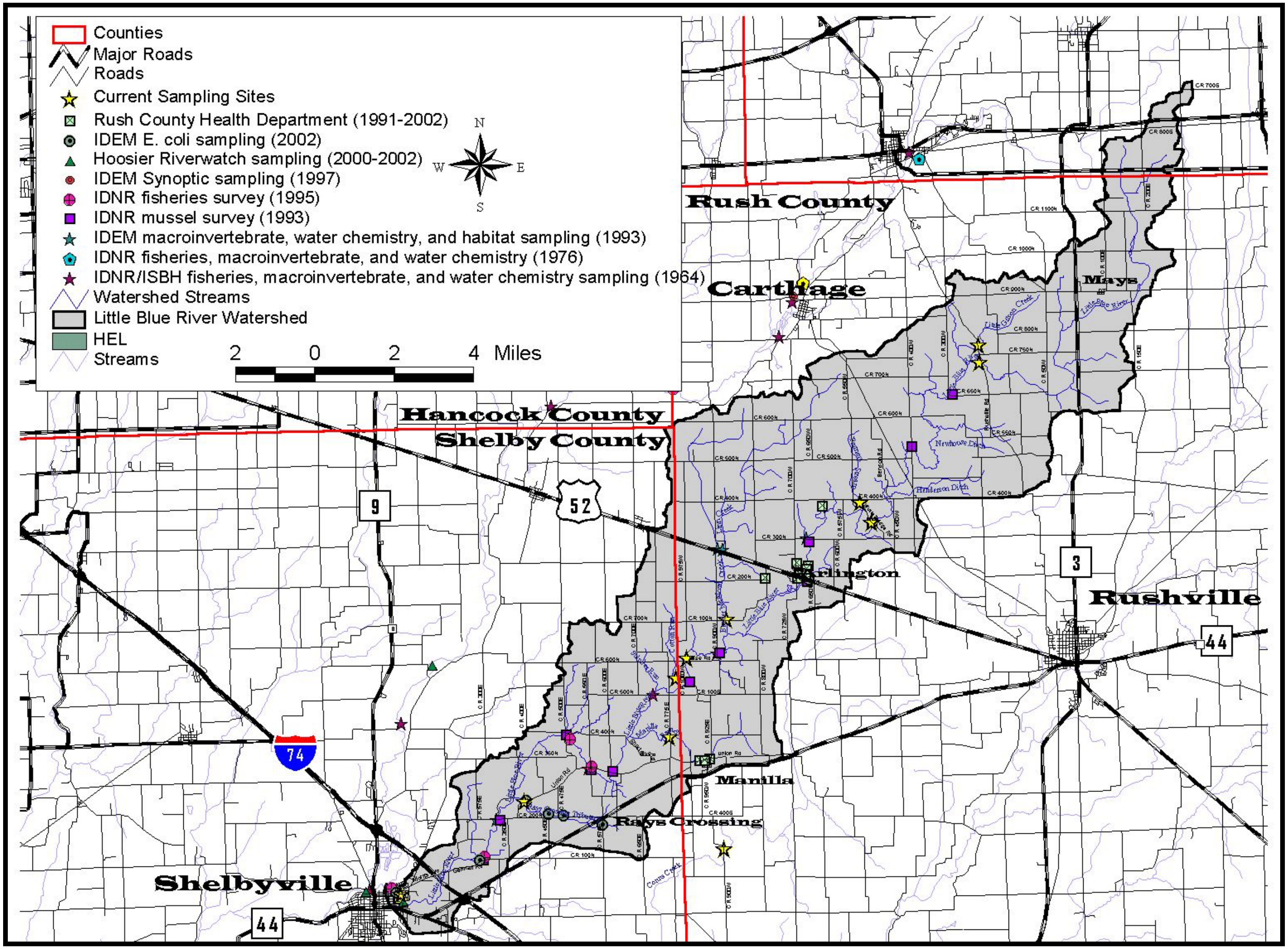


Figure 26. Historical water quality survey locations. Source: See Appendix A.

3.2.2 Indiana Department of Environmental Management Studies

IDEM assessed stream temperature, dissolved oxygen, conductivity, and pH as part of a macroinvertebrate sampling event in the Little Blue River and two of its tributaries in Shelby and Rush Counties in 1993 (Figure 26). All parameters were within ranges sufficient for aquatic life (Table 28).

Table 28. Little Blue River and tributary water chemistry collected at four locations by IDEM on July 27, 1993. Data marked with an asterisk (*) were collected August 24, 1993.

Site	County	Location	Temp	DO	pH	Cond
Beaver Meadow Creek	Rush County	State Road 52	22.57	6.73	7.86	656
Linn Creek	Rush County	Downstream of State Road 52	23.91	7.86	7.76	632
Little Blue River	Rush County	County Road 300 North	25.15	8.28	8.09	588
Little Blue River	Shelby County	County Road 200 North	24.23	7.72	7.92	522

Source: Todd Davis, IDEM Data Group
Temp=Temperature in ºC
Cond=Conductivity in μmhos/cm
DO=Dissolved oxygen in mg/l

IDEM sampled one site along the mainstem of the Little Blue River (German Road) during 1997 (Figure 26). Water sample collection occurred under the IDEM Office of Watershed Management Synoptic Sampling procedure. Synoptic sampling includes sampling individual sites over several seasonal periods during both base and storm flows. This sampling protocol will provide spatial scale water chemistry data to provide an overall assessment of individual water bodies by showing seasonal effects and the changes and movement of contaminants (Holderman et al., 1998). Tables 29 and 30 present data collected by IDEM during synoptic sampling conducted on five dates during 1997. Dissolved oxygen concentrations measured throughout the year exceeded 5 mg/l, the concentration required to support warmwater aquatic life (IAC, 2000). Conductivity, pH, and alkalinity all fell within acceptable ranges. Turbidity concentrations exceeded the USEPA recommended criteria for all samples except those collected during June and November sampling (USEPA, 2000). Total Kjeldahl nitrogen and total phosphorus concentrations measured in all samples were below the USEPA recommended nutrient criteria (USEPA, 2000). However, the total phosphorus sample collected in March exceeded the typical Indiana range of 0.01-0.17 mg/l (White, 1999). Nitrate-nitrogen concentrations in all samples except that collected during November exceeded the USEPA recommended criteria (0.633 mg/l; USEPA, 2000). Generally, nitrate-nitrogen concentrations were also in excess of the concentration recommended by the Ohio EPA for the protection of aquatic life. *E. coli* concentrations exceeded the Indiana state standard on only one occasion during the sampling period. All metals concentrations fell below both acute and chronic aquatic criteria established for the state of Indiana (IAC, 2000).

Table 29. Little Blue River stream chemistry data gathered at German Road by IDEM on six sample dates in 1997.

Date	Temp	DO	pH	Cond	Alk	TOC	Turb	TS	TSS	TDS	NO_3-N	TKN	TP	*E. coli*
3/4/1997	7.3	11.0	8.0	420	160	3.0	125.0	360	62	240	4.8	1.8	0.27	--
4/18/1997	8.4	11.8	8.2	537	220	1.8	34.6	380	8	300	5	0.44	0.11	--
5/29/1997	14.4	9.2	8.3	--	230	3.0	4.1	410	6	340	7.8	1.1	0.07	700
7/18/1997	23.9	7.8	8.2	582	260	3.0	18.4	400	7	410	1.7	0.23	0.07	120
9/18/1997	18.5	8.4	8.2	581	260	4.0	17.0	380	6	350	1.7	0.51	0.12	190
11/14/1997	3.0	10.8	8.1	634	270	7.1	4.4	380	<4	350	0.2	0.45	0.06	--

Source: Chuck Bell, IDEM Data Group
Temp=Temperature in °C
DO=Dissolved oxygen in mg/l
Cond=Conductivity in μmhos/cm
Alk=Alkalinity as $CaCO_3$ in mg/l
TOC=Total organic carbon in mg/l
Turb=Turbidity in Nephelometric Turbidity Units (NTU)
TS=Total solids in mg/l
TSS=Total suspended solids in mg/l
TDS=Total dissolved solids in mg/l
NO_3-N=Nitrate-nitrogen in mg/l
TKN=Total Kjeldahl nitrogen in mg/l
TP=Total phosphorus in mg/l
E. coli=*Escherichia coli* in colonies/100 ml

Table 30. Little Blue River stream chemistry data gathered at German Road by IDEM on six sample dates in 1997.

Date	SO_4	Hard.	Ars.	Cad.	Chl.	Chrom.	Copper	Iron	Lead	Mercury	Nickel
3/4/1997	24	230	<2	<1	15	2.9	3.6	2600	2.5	<0.2	2.4
4/18/1997	30	290	<2	<1	18	<1	1.7	468	<1	<0.2	3.9
5/29/1997	33	330	<2	<1	23	<1	<1	151	<1	<0.2	2.6
7/18/1997	40	320	<2	<1	21	<1	1.1	219	<1	<0.2	3
9/18/1997	37	300	<2	<1	18	<1	1	142	<1	<0.2	3
11/14/1997	39	350	<2	<1	21	<1	<1	110	<1	<0.2	3.3

Source: Chuck Bell, IDEM Data Group
SO4=Sulfate in mg/l
Hard=Hardness as $CaCO_3$ in mg/l
Ars=Arsenic in μg/l
Cad=Cadmium in μg/l
Chl=Chloride in mg/l
Chrom=Chromium in μg/l
Copper=Copper in μg/l
Iron=Iron in μg/l
Lead=Lead in μg/l
Mercury=Mercury in μg/l
Nickel=Nickel in μg/l

IDEM also measured several stream parameters including turbidity and *E. coli* five times at three locations along the Little Blue River and four locations along the Rays Crossing Tributary in 2002 (Figures 26 and 27; Table 31). Temperature, pH, and conductivity were all within ranges appropriate for warmwater aquatic life (Table 31). None of the dissolved oxygen concentrations were below 5 mg/l, the concentrations required to support warmwater aquatic life. Dissolved oxygen saturation was low (62-72%) in four of the five samples collected at the US 52 site. Three of the Rays Crossing Tributary sites (CR 200 N, CR 475 E and Union Road) contained high dissolved oxygen saturation (108-159%) indicating high productivity at these three sites. *E. coli* concentrations exceeded the state standard for single samples (235 colonies/100 ml) at all seven sites; concentrations exceeded the state standard in all five samples collected at the four Rays Crossing Tributary locations (Table 31). The state standard for five-sample geometric means (125 colonies/100 ml) was also exceeded at all sites except US 52 (Figure 27). Silcox et al. (2001) noted that turbidities greater than 83 NTU often correlated with *E. coli* concentrations in excess of the state standard for single samples. This statistically significant relationship ($p<0.001$) applied to all samples collected in the Kankakee and Lower Wabash River Watersheds, indicating that runoff was one of the main factors affecting *E. coli* concentrations. However, turbidity concentrations less than 83 NTU did not always correlate in *E. coli* concentrations lower than 235 colonies/100 ml, which indicated that other environmental and anthropogenic factors were also responsible for the elevated *E. coli* concentrations (Silcox et al., 2001). In the Little Blue River Watershed, turbidities were generally less than 83 NTUs, while *E. coli* concentrations typically exceeded the state standard. Environmental and anthropogenic factors were likely the major factors affecting *E. coli* concentration determination in the Little Blue River Watershed streams.

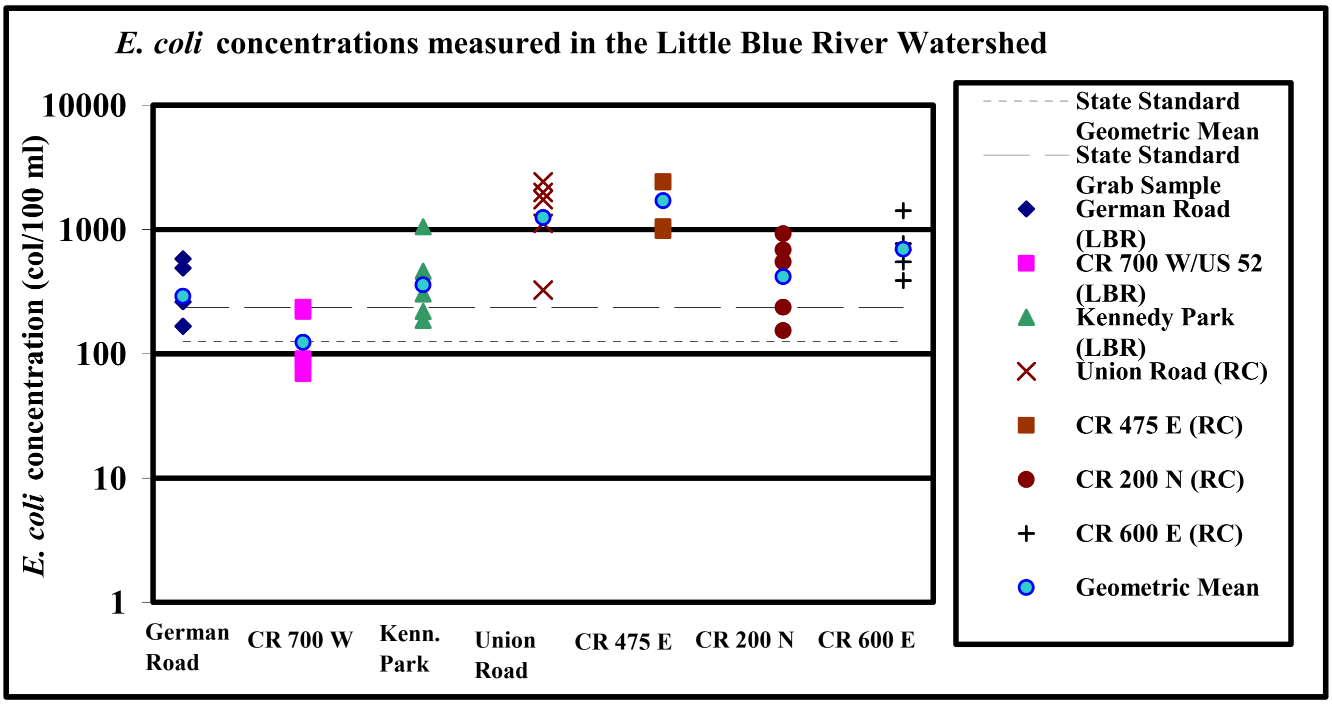


Figure 27. Concentrations of *E. coli* and five-sample geometric means for seven locations in the Little Blue River Watershed.
Note: LBR=Little Blue River; RC=Rays Crossing Tributary

Table 31. Little Blue River and Rays Crossing Tributary stream chemistry data collected at seven locations by IDEM.

Location	Date	Temp.	DO	DO % Sat	pH	Cond.	Turb.	*E. coli*
Little Blue River (CR 700 W/US 52)	9/11/2002	22.8	6.0	71.7	7.8	653	10.8	88
	9/18/2002	21.5	5.9	69.4	7.6	667	10.0	69
	9/25/2002	16.6	6.0	62.7	7.7	665	12.6	236
	10/2/2002	21.3	5.3	61.5	7.6	674	9.8	219
	10/9/2002	14.3	8.8	88.9	7.7	649	12.1	91
Little Blue River (German Road)	9/11/2002	20.0	6.7	76.1	7.7	630	4.1	488
	9/18/2002	19.6	6.0	68.2	7.5	651	9.3	166
	9/25/2002	15.5	8.2	84.3	7.8	561	4.5	261
	10/2/2002	20.4	6.8	78.4	7.8	559	3.3	167
	10/9/2002	13.8	8.6	85.2	7.7	551	2.9	579
Little Blue River (Kennedy Park)	6/3/2002	21.3	9.3	105	8.2	614	3.7	303
	6/10/2002	21.8	9.2	108.2	8.2	616	2.0	219
	6/17/2002	18.0	9.2	99.5	8.2	614	1.6	185
	6/24/2002	23.1	8.6	93.5	8.0	636	1.6	461
	7/1/2002	24.0	8.5	94.6	8.0	647	3.3	1046
Rays Crossing Tributary (CR 600 E)	6/3/2002	21.6	14.0	105.5	8.3	581	20.5	387
	6/10/2002	22.2	10.4	105.3	8.2	616	20.7	548
	6/17/2002	18.3	13.3	97.3	8.2	584	56.7	1414
	6/24/2002	22.3	12.6	100.9	8.2	637	22.3	770
	7/1/2002	23.0	11.6	101.6	8.2	636	13.5	687
Rays Crossing Tributary (CR 200 N)	6/3/2002	24.3	13.9	159.2	8.5	552	4.0	687
	6/10/2002	25.4	14.3	119.3	8.4	592	15.3	921
	6/17/2002	19.2	13.6	141.9	8.3	568	2.6	153
	6/24/2002	25.3	8.4	145.4	8.1	599	4.6	236
	7/1/2002	25.7	10.4	135.8	8.1	625	4.0	548
Rays Crossing Tributary (CR 475 E)	6/3/2002	22.7	11.2	167.8	8.5	601	25.2	1046
	6/10/2002	23.5	11.3	175.3	8.4	591	64.5	>2420
	6/17/2002	18.7	12.1	147.4	8.4	597	6.3	980
	6/24/2002	23.7	10.2	102.2	7.9	626	395.0	>2420
	7/1/2002	23.9	9.1	127.1	8.1	639	23.6	>2420
Rays Crossing Tributary (Union Road)	6/3/2002	21.0	9.3	130.4	8.3	631	10.3	1120
	6/10/2002	21.4	9.6	133.3	8.4	597	13.0	326
	6/17/2002	17.1	9.6	129.8	8.3	626	1.5	1986
	6/24/2002	21.8	8.2	120.4	7.9	632	7.5	1733
	7/1/2002	22.3	8.2	108.2	8.0	652	12.8	>2420

Source: Chuck Bell, IDEM Data Group
Temp=Temperature in ºC
DO=Dissolved oxygen in mg/l
DO % Sat=Percent saturation of dissolved oxygen
Cond=Conductivity in µmhos/cm
Turb=Turbidity in Nephelometric Turbidity Units (NTU)
E. coli=*Escherichia coli* in colonies/ml

3.2.3 Indiana Department of Natural Resources Study

The Indiana Department of Natural Resources assessed stream temperature, dissolved oxygen, pH, alkalinity, conductivity, and Secchi disk transparency as part of a fishery survey conducted in the Little Blue River in Shelby County in 1995 (Figure 26; Carnahan, 1995). All parameters were within ranges sufficient for aquatic life; however, pH levels were high possibly indicating high algal productivity in the water (Table 32).

Table 32. Little Blue River water chemistry data collected by the IDNR during a fishery survey conducted during the spring of 1995.

	Temp	DO	pH	Alkalinity	Conductivity	Secchi Disk Depth
Little Blue River						
River mile 0.3	18.9	8	9.0	205.2	499	1.3
River mile 5.0	17.2	8	9.0	256.5	528	1.2
River mile 10.4	18.9	9	8.5	239.4	529	2.2
River mile 11.5	18.9	8	8.5	239.4	538	1.5

Source: Carnahan, 1996.
Temp=Temperature in ºC
DO=Dissolved oxygen in mg/l
Alkalinity=Alkalinity as $CaCO_3$ in mg/l
Cond=Conductivity in μmhos/cm
Secchi Disk Depth=Transparency in feet

3.2.4 Hoosier Riverwatch Study

Hoosier Riverwatch volunteers sampled water chemistry in the Little Blue River at Kennedy Park (Figure 26; Table 33). Participating volunteers measured nine different water quality parameters as described by the Hoosier Riverwatch guidelines (Hartman and Burk, 2000). Data for each parameter was assigned a quality value; the Water Quality Index (WQI) for the site was then calculated by summing the individual parameter values. Overall, Little Blue River water quality possessed a WQI of fair to good (Table 33). Little Blue River habitat was also scored on multiple occasions using the Citizens Qualitative Habitat Evaluation Index (CQHEI; Table 34). The Kennedy Park site received moderately good depth/velocity and riffle run scores; riparian quality and stream shape scores. Generally, human alterations limited habitat quality.

Table 33. Little Blue River water chemistry data and Water Quality Index (WQI) values gathered by Hoosier Riverwatch volunteers. A WQI score of 4 indicates excellent, 3 indicates good, 2 indicates fair, and 1 indicates poor water quality (Hartman and Burk, 2000).

Site	Date	Temp Δ	% Sat	pH	Turb	BOD	NO_3-N	OP	Fecal	WQI
Kennedy Park	10/24/2001	0-2	90-71	6 or 8	40-100	6-8	>5	4	--	2.43
	1/28/2002	0-2	<50	6 or 8	0-40	0	1-4	0-1	301-500	3
	6/7/2002	0-2	90-71	6 or 8	40-100	2-4	>5	4	>500	2.38
	8/23/2002	0-2	90-71	6 or 8	0-40	2-4	1-4	2	301-500	3
	10/23/2002	0-2	90-71	6 or 8	0	2-4	0	0-1	0	3.62

Source: Hoosier Riverwatch database.
Temp Δ=Temperature change upstream to downstream in degrees
% Sat=Percent dissolved oxygen saturation
Turb=Turbidity in Nephelometric Turbidity Units (NTUs)
BOD=Biological oxygen demand in mg/l
NO_3-N=Nitrate-nitrogen in mg/l
OP=Orthophosphate in mg/l
Fecal=Fecal coliform in colonies/100 ml
WQI=Water Quality Index

Table 34. Little Blue and Big Blue River habitat data and Citizens Qualitative Habitat Evaluation Index (CQHEI) values gathered by Hoosier Riverwatch volunteers. Maximum CQHEI is 110 points; quality ratings have not yet been developed (Hartman and Burk, 2000).

Location	Date	I	II	III	IV	V	VI	CQHEI
Maximum Possible Score		**24**	**20**	**20**	**20**	**11**	**15**	**110**
Kennedy Park	8/23/2002	10	14	9	10	8	8	59
	10/23/2002	14	14	12	10	8	13	71

Source: Hoosier Riverwatch database.
I=Substrate (bottom type)
II=Fish cover (hiding places)
III=Stream shape and human alterations
IV=Stream forests and wetlands (riparian area) and erosion
V=Depth and velocity
VI=Riffles/runs

3.2.5 Indiana State Board of Health Study

The Indiana State Board of Health collected water chemistry samples in conjunction with a 1964 survey of fish and macroinvertebrate communities in the Little Blue River (Figure 26). Generally, water chemistry samples collected during the study were at levels that support productive biotic communities (Table 35). Temperature, pH, alkalinity, BOD, chloride, and sulfate concentrations were within ranges required to support warmwater biotic communities. Total nitrogen and total phosphorous concentrations were low and biologists did not note any nuisance populations of algae. Silt and other solid deposition was limited; ISHB biologists indicated that there was little evidence that solids impaired biotic health (Lockard and Winters, 1964).

Table 35. Little Blue River stream chemistry data gathered from the Little Blue River at Union Road by the Indiana State Board of Health in conjunction with macroinvertebrate and fish community surveys conducted in 1964.

Site	County	DO	%Sat	Temp	pH	Alk	BOD	TS	TN	TP	Cl	SO_4	Coliform
Union Road	Shelby	--	--	21	7.9	230	1	333	0	0	2	38	4,300

Source: Lockard and Winters, 1964.
DO=Dissolved oxygen in mg/l
%Sat=Percent oxygen saturation
Temp=Temperature in degrees Celsius
Alk=Alkalinity as $CaCO_3$ in mg/l
BOD=Biological oxygen demand in mg/l
TS=Total solids in mg/l
TN=Total nitrogen in mg/l
TP=Total phosphorus in mg/l
Cl=Chloride in mg/l
SO_4=Sulfate in mg/l
Coliform=Total coliform bacteria in colonies/100 ml

3.2.6 IDEM 303(d) List

Once every two years, IDEM publishes the 305(b) report, which documents the status of water quality in the state of Indiana. The 305(b) report includes the 303(d) list which names the "impaired waterbodies" that will be targeted for Total Maximum Daily Load (TMDL) development in the future. The Little Blue River is included on the 303(d) list for possessing high *E. coli* levels (IDEM, 2003; Figure 28). (Table 27 contains water quality data collected by the IDEM Assessment Branch in 2002 which exceeded the state standard for *E. coli* at most of the sampling sites.) Additionally, *E. coli* and polychlorinated biphenyls (PCBs) currently impair the water quality of the Big Blue River. Because previous studies have shown elevated concentrations of *E. coli* at sites throughout the watershed, this parameter is of concern in the entire Little Blue River Watershed.

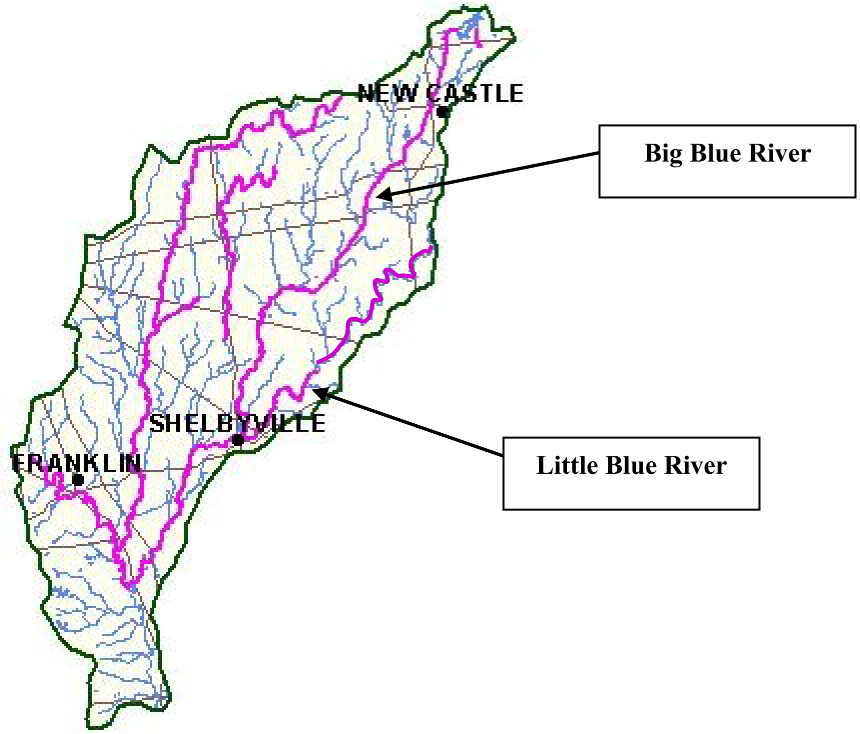


Figure 28. 303(d) listed waterbodies in the Driftwood River Basin. All bodies of water are displayed on the map. Those waterbodies included on the 303(d) list are highlighted in pink.

4.0 <u>HISTORICAL BIOLOGY OF THE WATERSHED</u>

4.1 HISTORICAL HABITAT STUDIES

The Indiana Department of Environmental Management evaluated the instream and riparian habitat of the Little Blue River and its major tributaries during 1993 and by the Indiana Department of Natural Resources in 1995 (Figure 26). Habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI). The Ohio Environmental Protection Agency (Ohio EPA) developed the QHEI for streams and rivers in Ohio (Rankin 1989, 1995); however, IDEM uses it to evaluate Indiana streams. The QHEI is a physical habitat index designed to provide an empirical, quantified evaluation of the general lotic macrohabitat (Ohio EPA, 1989). While the Ohio EPA originally developed the QHEI to evaluate fish habitat in streams, IDEM and other agencies routinely utilize the QHEI as a measure of general "habitat" health. The QHEI is composed of six metrics including substrate composition, instream cover, channel morphology, riparian zone and bank erosion, pool/glide and riffle-run quality, and map gradient. Each metric is scored individually then summed to provide the total QHEI score. The best possible score is 100.

The QHEI evaluates the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. QHEI scores from hundreds of stream segments in Ohio have indicated that values greater than 60 are *generally* conducive to the existence of warmwater faunas. Scores greater than 75 typify habitat conditions that have the ability to support exceptional warmwater faunas (Ohio EPA, 1999). IDEM indicates that QHEI scores above 64 suggest the habitat is capable of supporting a balanced warmwater community; scores between 51 and 64 are only partially supportive of a stream's aquatic life use designation (IDEM, 2000). (A more detailed discussion of the QHEI and its metrics is included in the Habitat Methods Section.)

4.1.1 IDEM Study

IDEM assessed habitat at three locations along the Little Blue River and at two tributaries within the Little Blue River Watershed in conjunction with macroinvertebrate community monitoring (Figure 26). All sites assessed during the 1993 macroinvertebrate survey were partially or fully supporting for aquatic life use according to IDEM's criteria (Table 36). The mainstem of the Little Blue River possessed higher quality habitat than its tributaries. The Little Blue River tributaries possessed relatively poor habitat quality, receiving QHEI scores of 52 and 55. The poor scores were generally due to poor riffle and pool development, limited riparian cover, insufficient channel development, and poor substrate.

Table 36. Qualitative Habitat Evaluation Index (QHEI) scores for sites on the Little Blue River and its tributaries as assessed by the IDEM Biological Studies Section during 1993.

Site	County	Substrate	Cover	Channel	Riparian	Pool	Riffle	Gradient	Total
Little Blue River									
CR 300 N	Rush	13	14	15	9	9	3	10	**73**
CR 200 N	Shelby	15	11	19	5	8	5	8	**71**
Beaver Meadow Creek	Rush	12	13	10	7	6	1	6	**55**
Linn Creek	Rush	13	12	14	7	2	0	4	**52**
Maximum Possible Score		**20**	**20**	**20**	**10**	**12**	**8**	**10**	**100**

Source: Todd Davis, IDEM Data Group; Dufour, 2000.

4.1.2 IDNR Study

IDNR assessed habitat at four locations along the Little Blue River in conjunction with a fisheries survey conducted in 1995 (Figure 26). All sites assessed during the fisheries survey were fully supporting for aquatic life use according to IDEM's criteria (Table 37). Generally, the mainstem of the Little Blue River possessed habitat that rated as fully supporting for aquatic life use. High substrate, channel development, pool development, and riffle development metric scores accounted for the high QHEI scores for reaches along the Little Blue River.

Table 37. Qualitative Habitat Evaluation Index (QHEI) scores for sites on the Little Blue River as assessed by the IDNR Division of Fish and Wildlife during 1995.

	County	Substrate	Cover	Channel	Riparian	Pool	Riffle	Gradient	Total
Little Blue River									
River mile 0.3	Shelby	18	11	11.5	4.5	9	5	10	**69**
River mile 5.0	Shelby	16	11	13	3	9	5	10	**67**
River mile 10.4	Shelby	18	6	16	4	9	5	10	**68**
River mile 11.5	Shelby	16	11	14	3	10	4	10	**68**
Maximum Possible Score		**20**	**20**	**20**	**10**	**12**	**8**	**10**	**100**

Source: Carnahan, 1996.

4.2 HISTORICAL MACROINVERTEBRATE STUDIES

Macroinvertebrate community studies have been conducted in the Little Blue River Watershed by both the Indiana Department of Natural Resources and the Indiana Department of Environmental Management (Figure 26). IDNR assessed the macroinvertebrate community of the Little Blue River in conjunction with a fisheries survey conducted in 1964 (Figure B). IDEM characterized the macroinvertebrate communities at four sites in the Little Blue River Watershed in 1993 (Figure 26).

4.2.1 IDNR Study

The Indiana Department of Natural Resources and the Indiana State Board of Health assessed the macroinvertebrate community of the Little Blue River in conjunction with water quality sampling and a fisheries survey conducted in 1964 (Figure 26). IDNR biologists collected individuals representing 22 genera. Biologists concluded that macroinvertebrate communities observed in the Little Blue River at Union Road were impaired due to mild pollution levels and poor substrate conditions (Lockard and Winters, 1964).

4.2.2 IDEM Study

IDEM assessed the macroinvertebrate community at four sites in the Little Blue River Watershed using the macroinvertebrate Index of Biotic Integrity (mIBI). IDEM's mIBI is a multi-metric index designed to provide a complete assessment of a creek's biological integrity. The mIBI consists of ten metrics which measure the species richness, evenness, composition, and density of the benthic community at a given site. The metrics include family-level HBI (Hilsenhoff's Family Biotic Index (FBI)), number of taxa, number of individuals, percent dominant taxa, EPT Index, EPT count, EPT count to total number of individuals, EPT count to chironomid count, chironomid count, and total number of individuals to number of squares sorted. (EPT stands for the Ephemeroptera, Plecoptera, and Trichoptera orders.) A classification score of 0, 2, 4, 6, or 8 is assigned to specific ranges for metric values. For example, if the benthic community being assessed supports nine different families, that community would receive a classification score of 2 for the "Number of Taxa" metric. The mIBI is calculated by averaging the classification scores for the ten metrics. mIBI scores of 0-2 indicate the sampling site is severely impaired; scores of 2-4 indicate the site is moderately impaired; scores of 4-6 indicate the site is slightly impaired; and scores of 6-8 indicate that the site is non-impaired. (A more detailed discussion of the mIBI and its metrics is included in the Macroinvertebrate Methods Section.)

The mainstem of the Little Blue River contained the relatively healthy macroinvertebrate communities (Table 38). The mIBI scores for both mainstem sites indicate only slight water quality impairment (IDEM, unpublished). Linn Creek and Beaver Meadow Creek macroinvertebrate communities were moderately to slightly impaired (Table E). QHEI scores indicated that habitat at these sites was partially supporting for aquatic life use; the moderate to slight macroinvertebrate community impairment may be due to habitat limitation and/or poor water quality.

Table 38. Macroinvertebrate Index of Biotic Integrity (mIBI) scores for the the Little Blue River and two of its tributaries samples by the IDEM during 1993.

	Value	Metric Score
Little Blue River (CR 300 N; Shelby County)		
HBI	4.25	6
Number of Taxa (families)	19	8
Number of Individuals	161	4
% Dominant Taxa	25.5	6
EPT Index	8	8
EPT Count	87	4
EPT Count/Total Count	0.54	6
EPT Abundance/Chironomid Abundance	87	8
Chironomid Count	1	8
Number of Individuals/Square	80.5	4
mIBI Score		**6.2**
Little Blue River (CR 200 N; Rush County)		
HBI	4.43	6
Number of Taxa (families)	13	4
Number of Individuals	147	4
% Dominant Taxa	32.7	4
EPT Index	5	4
EPT Count	46	4
EPT Count/Total Count	0.31	4
EPT Abundance/Chironomid Abundance	3.29	4
Chironomid Count	14	6
Number of Individuals/Square	73.5	4
mIBI Score		**4.4**
Beaver Meadow Creek (SR 52)		
HBI	4.49	6
Number of Taxa (families)	12	4
Number of Individuals	275	6
% Dominant Taxa	34.9	4
EPT Index	2	0
EPT Count	64	4
EPT Count/Total Count	0.23	2
EPT Abundance/Chironomid Abundance	1.68	2
Chironomid Count	38	4
Number of Individuals/Square	275	6
mIBI Score		**3.8**

	Value	Metric Score
Linn Creek (downstream of SR 52)		
HBI	4.5	6
Number of Taxa (families)	14	4
Number of Individuals	166	4
% Dominant Taxa	34.3	4
EPT Index	5	4
EPT Count	41	2
EPT Count/Total Count	0.25	2
EPT Abundance/Chironomid Abundance	5.13	4
Chironomid Count	8	6
Number of Individuals/Square	166	4
mIBI Score		**4**

Source: Todd Davis, IDEM Data Group

4.3 HISTORICAL MUSSEL COMMUNITY STUDY

The IDNR Division of Fish and Wildlife Non-Game Section conducted a freshwater mussel survey in the Little Blue River Watershed in 1993 (Figure 26). Table 39 lists detailed location information for each of the sample sites. IDNR biologists identified 697 live individuals belonging to 18 species (Table 40). Biologists collected fresh dead or weathered shells from two additional species including pond papershell (*Anodonta imbecilis*) and clubshell (*Pleurobema clava*). All clubshell specimens were collected as fresh dead with intact or connected ligaments; this indicates little loss in overall stream diversity. Live specimen density ranged from no live individuals collected at the State Road 52 bridge (Site 4) to 375 individual collected at the Offutt Road Bridge (Site 3). Because the two sites were separated by only a few river miles and possessed similar substrates, IDNR biologists suggested that a water quality problem may exist between the two sites. The two most abundant species collected during the survey include the fluted-shell (*Lasmigona costata*) and the fatmucket (*Lampsilis siliquoidea*). Fluted-shells were especially abundant at the Offutts Bridge Road (Site 3) where species density was 2.7 individual per square meter. Fatmuckets were found live or as fresh dead shells at all sites (Harmon, 1993). Additionally, the Asian clam (*Corbicula fluminea*), an introduced species, was found at seven sites (Sites 6 to 12) along the lower portion of the Little Blue River. One state endangered species, the clubshell, and five species of state concern were collected during the survey.

Table 39. Mussel survey locations sampled during 1993 by IDNR.

Site Number	County	Sampling Location
Site 1	Rush	County Road 300 West; upstream 1000 feet
Site 2	Rush	County Road 400 West; upstream 1000 feet
Site 3	Rush	Offutts Bridge Road; upstream 1000 feet
Site 4	Rush	State Road 52; downstream 1000 feet
Site 5	Rush	County Road 900 west; upstream 1000 feet
Site 6	Shelby	Short Blue Road; upstream 750 feet
Site 7	Shelby	Union Road/County Road 650 East; upstream 500 feet
Site 8	Shelby	Union Road/County Road 575 East
Site 9	Shelby	County Road 500 East; upstream 1000 feet
Site 10	Shelby	County Road 350 North
Site 11	Shelby	County Road 200 North; upstream 300 feet to downstream 200 feet
Site 12	Shelby	Country Road 100 North/Old Rushville Road; upstream 750 feet

Table 40. Mussel species collected in the Little Blue River during the Indiana Department of Natural Resources survey conducted in 1993. X indicates the collection of fresh dead mussel shells; Y indicates the collection of weathered shells; A indicates that Asian clams were absent while P indicates that the species was present.

Common name	Scientific name	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12	Total
Asian clam*	*Corbicula fluminea*	A	A	A	A	A	P	P	P	P	P	P	P	
Anodontinae														
Elktoe	*Alasmidonta marginata*			8		3	2	1	1	2	1	Y	X	18
Slippershell mussel	*Alasmidonta viridis*	X	X	1	Y			Y	Y	Y		Y		1
Giant floater	*Anodonta grandis*	7	1	7		2		X	X	X				17
Paper pondshell	*Anodonta imbecillis*	X											X	--
Cylindrical papershell	*Anodontoides ferussacianus*	1		4	X	Y		X	X	Y			Y	5
White heelsplitter	*Lasmigona complanata*	1	1	21		7	7	X	6		5	Y		48
Creek heelsplitter	*Lasmigona comprssa*	1		5		1	1	X		X	X	X		8
Fluted-shell	*Lasmigona costata*			192	Y	2	20	1	12	11	9	X	1	248
Squawfoot	*Strophitus undulatus*			41		9	4	Y	X	X	1	X	X	55
Ambleminae														
Spike	*Ellipio dilatata*									X		2	X	2
Wabash pigtoe	*Fusconaia flava*	9	6	1		X	X	X	1	X	2	1	1	21
Clubshell	*Pleurobema clava*					Y	Y	Y	Y	Y	Y	Y	Y	--
Lampsilinae														
Plain pocketbook	*Lampsilis cardium*	1		13	Y	Y	2	Y	4	6	5	X	Y	31
Wavy-rayed lampmussel	*Lampsilis fasciola*			1		Y		Y	1	Y	X	Y	X	2
Fatmucket	*Lampsilis siliquoidea*	41	8	64	X	8	14	1	5	7	5	1	5	159
Kidneyshell	*Ptychobranchus fasciolaris*					1	20	X	26	2	9	X	1	59
Purple lilliput	*Toxolasma lividus*		1	5	Y		Y	Y		Y		Y	Y	6
Lilliput	*Toxolasma parvus*	Y	1	1										2
Rainbow	*Villosa iris*		X	3	X	X	X	X	X	2	X	X	Y	5
Little spectaclecase	*Villosa lienosa*	X	2	8		Y	Y	Y	Y	Y	Y	X	X	10
Number of live specimens		**61**	**20**	**375**	**0**	**33**	**70**	**3**	**56**	**30**	**37**	**4**	**8**	**697**
Number of live species		**7**	**7**	**16**	**0**	**8**	**8**	**3**	**8**	**6**	**8**	**3**	**4**	**18**
Total number of species		**11**	**9**	**16**	**7**	**15**	**13**	**17**	**15**	**17**	**13**	**16**	**15**	**20**

Source: Harmon, 1993
*IDNR biologists noted the presence or absence of *Corbicula fluminea* during the survey, but did not quantify the number of individuals at each sampling site.

4.4 HISTORICAL FISH COMMUNITY STUDIES

Two fisheries surveys have been conducted along the mainstem of the Little Blue River. Both were part of larger studies that included the Big Blue River as well. The first survey was conducted by the IDNR in 1964 in conjunction with the Indiana Stream Pollution Control Board. The survey occurred in response to reports of declining game fish populations along the Big Blue River. This survey included the assessment eight sites along the Big Blue River and two sites along the Little Blue River to establish reference conditions for the Big Blue River (Lockard and Winters, 1964). The second survey was conducted in 1995. The 1995 study was conducted as part of a statewide survey of fish communities and aquatic habitats along Indiana's major streams; the survey placed a special emphasis on smallmouth bass distribution and abundance. This survey included four sites on the Little Blue River (Carnahan, 1996).

4.4.1 Little Blue River Community Composition

The 1964 and 1995 IDNR surveys documented the presence of 46 fish species in the Little Blue River. In 1964, 28 total species were collected at 2 sites (Table 41). In 1995, 39 total species were collected at 4 sites (Table 41). Game fish and nongame fish species are well represented throughout the river. Species richness, or number of species, ranged from a low of 24 species to a high of 27 species per site in 1964 with a mean of value of 25 species between 2 sites (Table 41). In 1995, species richness ranged from a low of 21 species to a high of 30 species with a mean value of 24 among 4 sites (Table 41). The minnow family was the most abundant family by number and weight during the 1995 survey. During this time period several additions (17 taxa) and deletions (7 taxa) of fish species occurred. Six additional minnow species were present in the 1995 survey compared to 1964. However, two darter and one madtom species present in the 1964 survey were not collected in 1995 (Lockard and Winters, 1964; Carnahan, 1995). Both darter and madtom species are considered indicators of good water quality (Simon and Dufour, 1997).

Little Blue River Game Fish

Expansion of Centrarchidae, or sunfish family, populations is evident between the 1964 and 1995 surveys. Game fish species such as bluegill, rock bass, and smallmouth bass were represented at all of the sites surveyed in 1995 with varying relative abundance (Table 41). The number of game fish species and individual numbers were generally greatest near the lower reaches of the Little Blue River. The reduction in sunfish numbers and species at the upstream sampling locations may be a function of drainage area and the loss of valuable pool habitat required for these deep bodied fishes (Simon and Dufour, 1997).

Table 41. Fish captured during the 1964* and 1995 IDNR[§] survey of the Little Blue River.

Family	Common name	Scientific Name	CR 350 N*	W. Base Rd.*	RM 0.3	RM 5.0	RM 10.4	RM 11.5
Catostomidae	Creek chubsucker	*Erimyzon oblongus*		X				
	Golden redhorse	*Moxostoma erythrurum*	X	X	X	X	X	X
	Northern hogsucker	*Hypentelium nigricans*	X	X	X	X	X	X
	Quillback	*Carpiodes cyprinus*			X		X	
	River carpsucker	*Carpiodes carpio*			X			
	Spotted sucker	*Minytrema melanops*					X	
Centrarchidae	White sucker	*Catostomus commersoni*	X	X	X	X	X	X
	Black crappie	*Pomoxis nigromaculatus*			X			

Family	Common name	Scientific Name	CR 350 N*	W. Base Rd.*	RM 0.3	RM 5.0	RM 10.4	RM 11.5
	Bluegill	*Lepomis macrochirus*			X	X		
	Green sunfish	*Lepomis cyanellus*		X		X		
	Largemouth bass	*Micropterus salmoides*			X			
	Longear sunfish	*Lepomis megalotis*	X	X	X	X	X	X
	Redear sunfish	*Lepomis microlophus*			X			
	Rock bass	*Ambloplites rupestris*	X	X	X	X	X	X
	Smallmouth bass	*Micropterus dolomieu*	X	X	X	X	X	X
Clupeidae	White crappie	*Pomoxis annularis*			X			
Cottidae	Gizzard shad	*Dorosoma cepedianum*	X	X	X		X	
Cyprinidae	Banded sculpin	*Cottus carolinae*					X	X
	Mottled sculpin	*Cottus bairdi*	X	X				
	Bigeye chub	*Notropis amblops*			X	X		
	Bluntnose minnow	*Pimephales notatus*	X	X	X	X	X	X
	Central stoneroller	*Campostoma anomalum*	X	X	X	X	X	X
	Common carp	*Cyprinus carpio*	X	X	X		X	X
	Creek chub	*Semotilus atromaculatus*	X	X	X	X	X	X
	Emerald shiner	*Notropis atherinoides*			X	X	X	X
	Hornyhead chub	*Nocomis biguttatus*		X		X		
	Redfin shiner	*Lythrurus umbratilis*			X		X	
	Rosyface shiner	*Notropis rubellus*	X	X	X	X	X	X
	Sand shiner	*Notropis stramineus*		X	X	X	X	
	Silverjaw minnow	*Notropis buccatus*	X	X	X	X	X	
	Spotfin shiner	*Cyprinella spilopter*		X				
	Steelcolor shiner	*Cyprinella whipplei*			X	X	X	X
	Striped shiner	*Luxilus chrysocephalus*			X	X	X	X
	Suckermouth minnow	*Phenacobius mirabilis*	X	X				X
Esocidae	Grass pickerel	*Esox americanus*			X			
Ictaluridae	Brindled madtom	*Noturus miurus*	X	X				
Percidae	Channel catfish	*Ictalurus punctatus*	X	X				
	Yellow bullhead	*Ameiurus natalis*						X
	Blackside darter	*Percina maculata*	X	X				
	Fantail darter	*Etheostoma flabellare*	X	X				X
	Greenside darter	*Etheostoma blennioides*	X	X		X	X	X
	Johnny darter	*Etheostoma nigrum*	X	X		X	X	X
	Orangethroat darter	*Etheostoma spectabile*	X	X				
	Orangethroat darter	*Etheostoma spectabile*	X	X	X	X	X	X
	Rainbow darter	*Etheostoma caeruleum*	X	X	X			
Petromyzontidae	Silver lamprey	*Ichthyomyzon unicuspis*			X			
Number of Individuals			**--**	**--**	**546**	**412**	**504**	**359**
Number of Species			**24**	**27**	**30**	**22**	**24**	**21**
Number of Families			**7**	**7**	**5**	**4**	**6**	**6**

*The sample was collected during the 1964 survey. [§]The 1995 survey utilizes river mile notation as per (Hoggatt, 1975); these sites are listed in downstream to upstream order (i.e. RM 0.3 is located near Shelbyville).
Source: Lockard and Winters, 1964; Carnahan, 1996

A total of 65 smallmouth bass ranging in size from 1.7 to 15 inches was collected during the 1995 fall survey (Table 42). Smallmouth bass catch per unit effort ranged from 14 to 52 per hour of electrofishing with a mean of 32.5 smallmouth bass collected per hour. Growth rates of smallmouth bass were found to be lower than those collected from the Big Blue River. However, smallmouth bass growth rates were comparable to Brandywine Creek, which is similar in size to the Little Blue River (Carnahan, 1996).

Table 42. Selected game fish captured during the 1995 IDNR game fish survey of the Little Blue River. The survey utilizes river mile notation as per (Hoggatt, 1975); these sites are listed in downstream to upstream order (i.e. RM 0.3 is located near Shelbyville).

Common name	**Scientific Name**	**RM 0.3**	**RM 5.0**	**RM 10.4**	**RM 11.5**
Largemouth bass	*Micropterus salmoides*	**X**			
Rock bass	*Ambloplites rupestris*	**X**	**X**	**X**	**X**
Smallmouth bass	*Micropterus dolomieu*	**X**	**X**	**X**	**X**
Total Number of Species		**3**	**2**	**2**	**2**
Total Number of Individuals		**40**	**42**	**20**	**16**

Source: Carnahan, 1996

4.5 NATURAL COMMUNITIES AND ENDANGERED, THREATENED, AND RARE SPECIES

The Indiana Natural Heritage Data Center database provides information on the presence of endangered, threatened, and rare species, high quality natural communities, and natural areas in Indiana. The database was developed to assist in documenting the presence of special species and significant natural areas and to serve as a tool for setting management priorities in areas where special species or habitats exist. The database relies on observations from individuals rather than systematic field surveys by the Indiana Department of Natural Resources (IDNR). Because of this, it does not document every occurrence of special species or habitat. At the same time, the listing of species or natural areas does not guarantee that the listed species is present or that the listed area is in pristine condition. To assist users, the database includes the date that the species or special habitat was last observed and reported in a specific location.

Results from the database search for the Little Blue River Watershed are presented in Appendix E. (For additional reference, a listing of endangered, threatened, and rare species documented in Shelby, Rush, and Henry Counties is included in Appendix F.) According to the database, the Little Blue River Watershed supports one high quality community type within the study area: the Central Till Plain Flatwoods. Central Till Plain Flatwoods habitat or community was noted in one location in Posey Township north of Arlington. The database also lists sightings of one state endangered species, the clubshell (*Pleurobema clava*), a unionid species that has also been proposed for federally endangered status. Five other species of special concern, the wavy-rayed lampmussel (*Lampsilis fasciola*), the purple lilliput (*Toxolasma lividus*), the lilliput (*Toxolasma parvum*), the little spectaclecase (*Villosa lienosa*), and the kidneyshell (*Ptychopranchus fasciolaris*), have also been sighted in the Little Blue River Watershed. Two additional species, the great blue heron (*Ardea herodias*) and the slippershell mussel (*Alasmidonta viridis*) have also been observed in the watershed.

4.6 OUTSTANDING RIVERS LIST

In 1993, the Indiana Natural Resources Commission adopted its Outstanding Rivers List for Indiana. The list includes rivers and streams with special aesthetic or environmental interest that qualify for one of twenty-two categories. These categories include: federal Wild and Scenic Rivers, state designated scenic rivers, rivers listed on the Nationwide Rivers Inventory, rivers with hydropower bans, Atlantic Salmon Restoration Rivers, federal Public Lands Rivers, State Fishing Rivers, State Heritage Program Sites, Priority Aquatic Sites, rivers with designated canoe trails, and State Park rivers. Although the Little Blue River is not mentioned, the Big Blue River from the Flatrock River to Carthage is named as one of the sixty-five stream reaches that Indiana has included on its Outstanding Rivers List. This reach is directly influenced by the Little Blue River.

The Big Blue River is included on the Outstanding Rivers List for two reasons: it was identified by the National Park Service in its 1982 “Nationwide Rivers Inventory” (NRI) as one of nine Indiana rivers for inclusion on the NRI listing and it is a State Heritage Program Site (NRC, 1997). In order to be listed on the Nationwide Rivers Inventory a river must be free-flowing and possess one or more Outstanding Remarkable Value (ORV). The National Park Service defined six ORVs including scenery, recreation, geology, fish, wildlife, and prehistory. The National Park Service listed 55 miles of the Big Blue River on the Nationwide Rivers Inventory for three ORVs including recreation, fish, and wildlife. The Big Blue River was recognized as providing recreational opportunities that attract visitors from outside the region, supporting sensitive fish species, providing exceptional fisheries habitat, and providing habitat within the riparian corridor for and supporting nationally or regionally important indigenous wildlife populations (NRI, 2001). Specifically, the Nationwide Rivers Inventory cites the Big Blue River as offering good recreation potential, supporting heavy fishing and floating usage, providing exceptional instream habitat, and possessing ideal riparian areas which foster Indiana bat populations (NRI, 1982).

The Big Blue River’s inclusion as one of twenty State Heritage Sites also helped to earn the fifty-five mile segment a place on Indiana’s Outstanding Rivers List. The IDNR Division of Nature Preserves developed the State Heritage Site listing by assessing the presence of rare aquatic species. Documented species were then assigned importance values and a waterbody’s total score was computed. The top twenty stream segments were listed as State Heritage Sites. The Big Blue River ranks twelfth on the State Heritage Site listing and is included for the presence of multiple species of state endangered, threatened, and rare freshwater mussels (Cloyce Hedge, personal communication).

5.0 WATERSHED INVESTIGATION

5.1 INTRODUCTION

Identifying areas of concern and selecting sites for future management are the goals of the visual watershed inspection. The Little Blue River Watershed was toured by airplane in April 2003 and a windshield survey was conducted on December 2, 2003 after most crops were removed. The observations made during these two surveys are presented below. Figures 29 and 30 offer summary of observations made during both the aerial tour and the windshield survey.

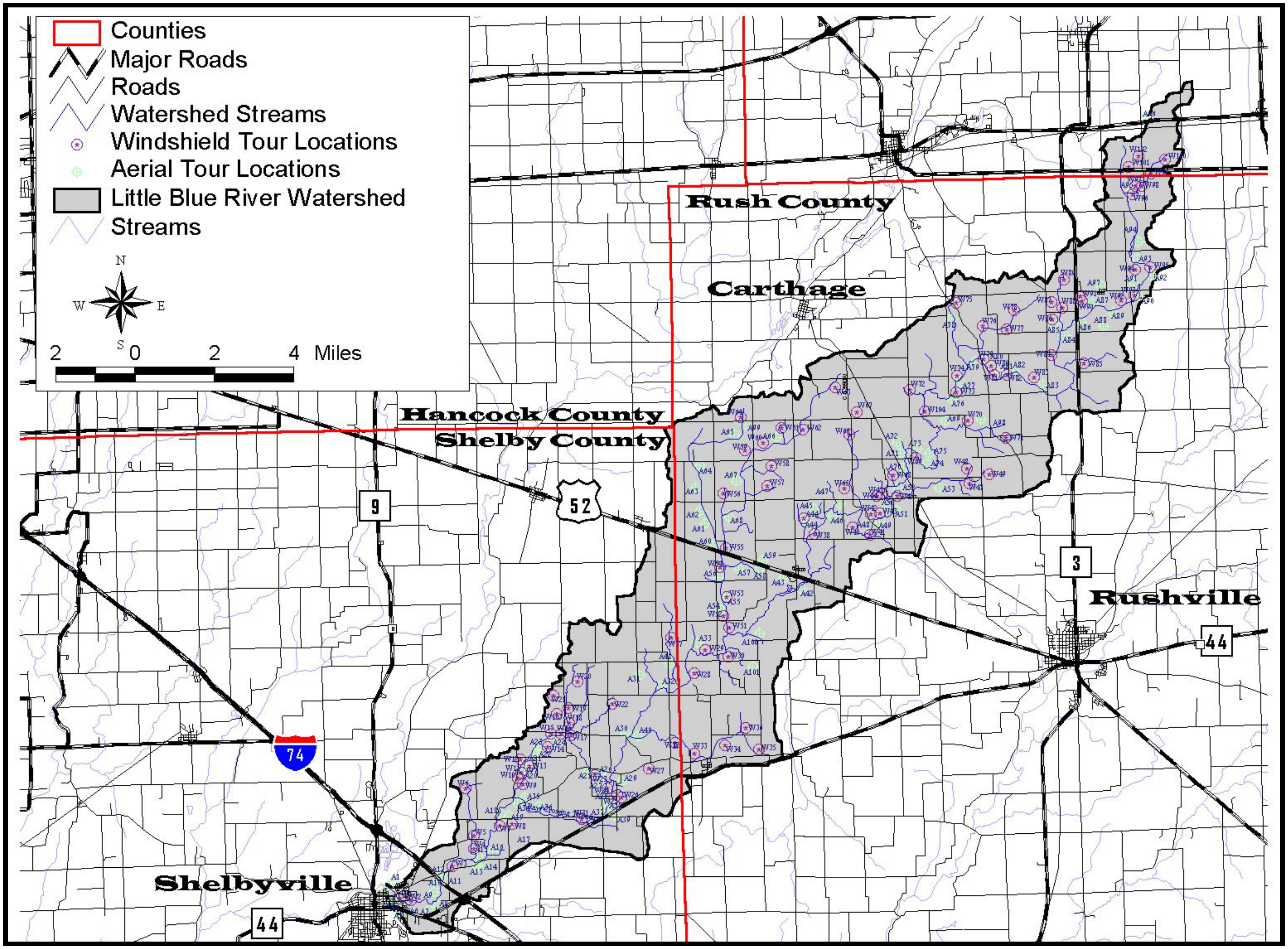


Figure 29. Aerial tour and windshield survey locations. Source: See Appendix A.

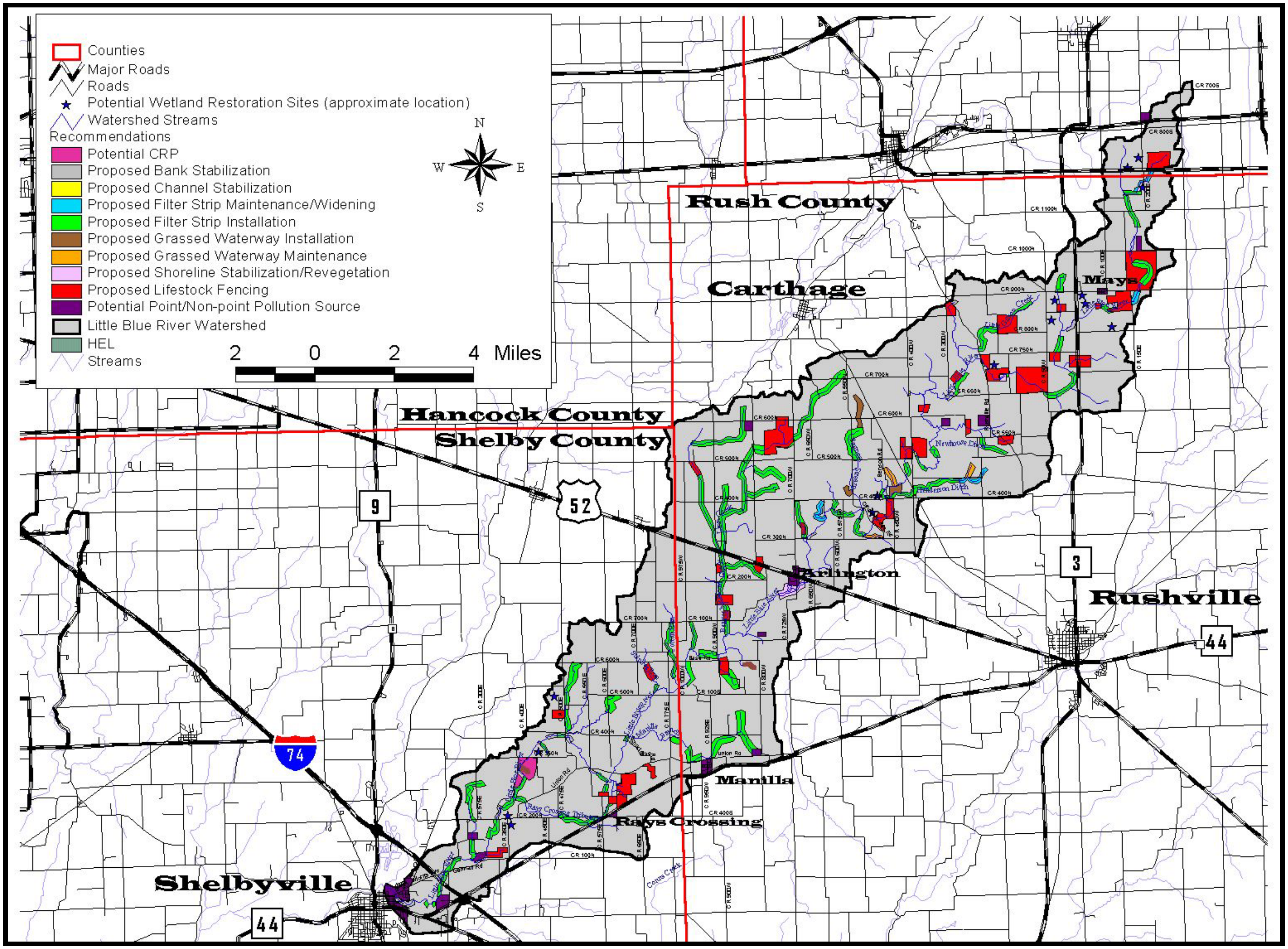


Figure 30. Recommendations for water quality improvement. Source: See Appendix A.

5.2 AERIAL TOUR

The aerial tour consisted of flying over the watershed at fairly low altitudes in order to photograph high priority and environmentally sensitive areas. Areas of concern with corresponding aerial photos are discussed by subwatershed; their locations are mapped on Figure 29. Specific locations where water quality improvement projects are recommended are mapped on Figure B. Photos of unique problems are included in the discussion of each subwatershed.

5.2.1 Lower Little Blue River Subwatershed

Table 43 lists the 34 sites in the Lower Little Blue River Subwatershed where land management actions could improve water quality (Table 43; Sites A1-A33, A101; Figure 29). Nine of these sites within the Lower Little Blue River Subwatershed were identified because they are potential pollution sources. These potential pollution sources include streamside factories, interstate stream crossings, construction projects, and refuse piled adjacent to the stream channel. Sediment and nutrients eroding from bare ground and debris associated with the construction of the new Walmart Supercenter near the intersection of State Road 44 and Interstate 74 could adversely affect the Little Blue River (Figure 31; Site A8). Once constructed, the store's sedimentation basin will discharge to the Little Blue River potentially contributing sediment, sediment-attached nutrients, hydrocarbons, and refuse to the stream channel from the parking lot. Biofilters should be installed between the basin and the river to reduce pollutant loading. Sites A1, A2, A3, A6, A8, A11, A13, and A15 are potential pollution sources where allowing riparian vegetation growth, implementing stormwater filtration measures, or ensuring that pollutants do not reach the stream channel from adjacent construction sites would help to maintain or improve water quality within the Little Blue River (Figure 29).

Ten locations including sites A4, A5, A9, A10, A14, and A20 were identified where riparian vegetation has been removed either through mowing, grazing, or farming to the stream's edge. Mowed turf grass adjacent to the Little Blue River's intersection with Interstate 74 provides limited filtration and generally allows stormwater to flow virtually unchecked into the Little Blue River (Figure 32; Site A10). Turf grass also provides poor riparian habitat. Water quality in the Little Blue River could be improved by protecting existing riparian vegetation or planting new riparian vegetation. Additionally, Figure 33 shows gully and rill erosion indicative of the need for grassed waterway installation at Site A21. Streambank erosion resulting from cutting at a natural bend in the stream channel is contributing sediment and sediment-attached nutrients to the Little Blue River (Figure 34; Site A23). Streambank stabilization and revegetation along this reach will reduce sediment and nutrient loads thereby improving water quality in the Little Blue River. Another prominent issue located throughout the Little Blue River Watershed is livestock grazing along the mainstem of and tributaries to the Little Blue River. Constant bank trampling can contribute sediment and sediment-attached pollutants to the Little Blue River. Disturbance to riparian vegetation impairs the riparian corridor's ability to filter pollutants from runoff, potentially increasing pollutant loads reaching the stream. Figure 35 displays pastures adjacent to a minor tributary to the Little Blue River at Site A29; both herds of cattle contribute to sediment, nutrient, and pathogen loading by trampling banks, removing riparian vegetation, depositing fecal matter, and resuspending sediments when traveling into and out of the stream when water is present in this tributary. The downstream pasture is likely subject to increased overland flows due to the extremely sparse vegetative cover; larger volumes of overland flows typically carry higher sediment and nutrient loads due to the shear volume of water moving across the land, thereby loading more sediment and nutrients to the Little Blue River. Livestock should be fenced away from streams and riparian areas at Sites A16, A27, A28, A29, A30, and A32; additionally, livestock should be fenced or removed from the downstream pasture at Site A29 so that vegetation can cover this pasture before the herd is reintroduced. Additionally, pasture renovation, providing an alternate water source, and grazing management should accompany any efforts to restrict livestock access to the Little Blue River or its tributaries.

Table 43. List of locations where the application of best management practices would improve water quality in nearby waterbodies as photographed during the aerial tour of the Lower Little Blue River Subwatershed. The issues of concern and practices that could be used to treat the concern(s) are also listed.

Site	Concern	Management Practice
A1	Potential pollution source: Streamside factory	Urban BMPs
A2	Potential pollution source: City of Shelbyville	Urban BMPs
A3	Potential pollution source: Streamside ponds (thermal pollution)	On the ground investigation is needed to determine BMP
A4	Vegetation is mowed to stream's edge	Restore riparian habitat
A5	Vegetation is mowed to stream's edge	Restore riparian habitat
A6	Potential pollution source: County fairgrounds	On the ground investigation is needed to determine BMP
A7	Land is farmed to stream's edge	Filter strip installation
A8	Potential pollution source: Walmart construction; Sedimentation basin outlets to stream (Figure 31)	Erosion control during construction; Biofilter or other urban BMP to treat stormwater
A9	Vegetation is mowed to stream's edge	Restore riparian habitat
A10	Vegetation is mowed to stream's edge; stream banks are eroding (Figure 32)	Restore riparian habitat; Stabilize stream banks
A11	Potential pollution source: I-74 crossing	Urban BMPs
A12	Land is farmed to stream's edge	Filter strip installation
A13	Potential pollution source: Bridge construction	Urban BMPs
A14	Vegetation is mowed to stream's edge	Restore riparian habitat
A15	Potential pollution source: Subdivision construction	Urban BMPs
A16	Land appears to be heavily grazed*	Livestock fencing; Restore riparian habitat; Filter strip installation
A17	NA	Wetland restoration is possible
A18	Banks are eroding	Stabilize streambanks; Restore riparian habitat
A19	NA	Wetland restoration is possible
A20	Natural vegetation has been removed	Restore riparian habitat

Site	Concern	Management Practice
A21	Rill and gully erosion is evident (Figure 33)	Grassed waterway installation
A22	Potential pollution source: Motor bike track	On the ground investigation is needed to determine BMP
A23	Stream crossing appears to cause bed erosion (Figure 34)	Stabilize stream bed
A24	Banks are eroding	Stabilize stream banks; Restore riparian habitat
A25	Banks are eroding	Stabilize stream banks; Restore riparian habitat
A26	Banks are eroding	Stabilize stream banks; Restore riparian habitat
A27	Natural vegetation has been removed	Restore riparian habitat; Stabilize stream banks
A28	Land appears to be heavily grazed*	Livestock fencing; Restore riparian habitat; Filter strip installation
A29	Land appears to be heavily grazed* (Figure 35)	Livestock fencing; Restore riparian habitat; Filter strip installation
A30	Land appears to be heavily grazed*	Livestock fencing; Restore riparian habitat; Filter strip installation
A31	Land is farmed to stream's edge	Filter strip installation
A32	Land appears to be heavily grazed*	Livestock fencing; Restore riparian habitat; Filter strip installation
A33	Land is farmed to stream's edge	Filter strip installation
A101	Rill and gully erosion is evident	Grassed waterway installation

*Pasture renovation, providing an alternate water source, and grazing management are also possible management practices for this concern.

Figure 31. Site A8 showing construction of the new Walmart Supercenter store, parking lot, and detention basin. The detention basin outlets directly to the Little Blue River (top of picture).

Figure 32. Site A10 showing turf grass mowed to the stream's edge at the intersection of the Little Blue River with Interstate 74.

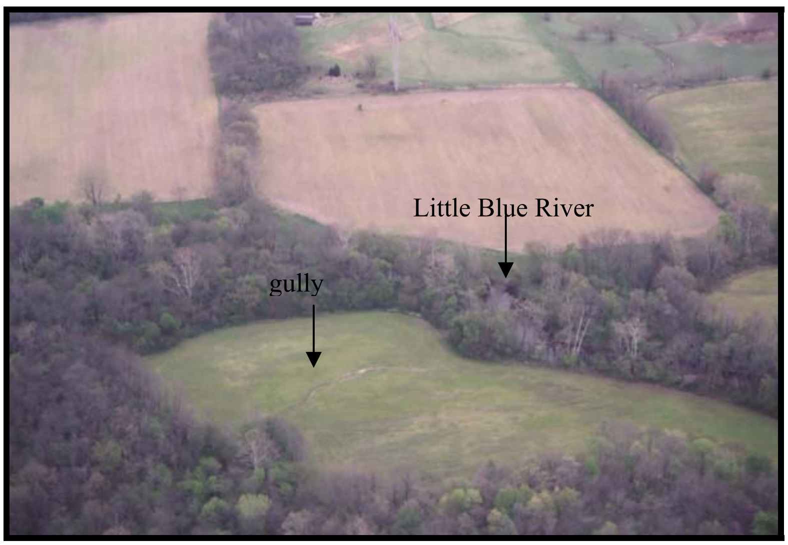


Figure 33. Site A21 showing the representative need for grassed waterway installation.

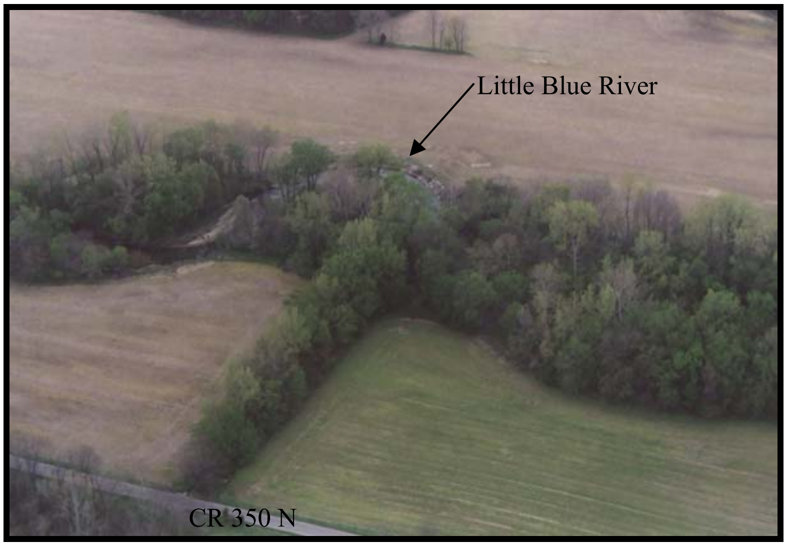


Figure 34. Site A23 showing streambank erosion at a bend in the Little Blue River.

Figure 35. Site A29 showing area of heavy grazing in the Lower Little Blue River Subwatershed.

5.2.2 Rays Crossing Tributary Subwatershed

Six areas that would benefit from management practices were documented during the aerial tour of the Rays Crossing Tributary Subwatershed (Table 44; Sites A34-A39; Figure 29). Riparian revegetation and filter strips would help to slow erosion at three of the sites. Remnant wetlands and hydric soils were evident at Sites A34 and A35 (Figures 29 and 36) where wetland restoration could be possible. Wetlands increase water storage capacity in the watershed, thereby reducing runoff volumes during storm events. Large runoff events can erode soil from the landscape. Large volumes of water that reach stream channels can erode the channel bed and banks as well. Wetlands also offer mechanical and biological filtration of water that removes some of the sediment, pathogens, nutrients, and other chemicals from runoff. An additional area of concern in the Rays Crossing Tributary Subwatershed is the livestock grazing along the northern tributary at Site A39. Livestock setbank zones should be considered at this site where banks and riparian areas appear to have been overgrazed.

Table 44. List of locations where the application of best management practices would improve water quality in nearby waterbodies as photographed during the aerial tour of the Rays Crossing Tributary Subwatershed. The issues of concern and practices that could be used to treat the concern(s) are also listed.

Site	Concern	Management Practice
A34	NA (Figure 36)	Wetland restoration is possible
A35	NA (Figure 36)	Wetland restoration is possible
A36	Vegetation is mowed to stream's edge	Restore riparian habitat
A37	Potential pollution source: Town of Rays Crossing Tributary	Urban BMPs
A38	Land is farmed to stream's edge	Filter strip installation
A39	Land appears to be heavily grazed*; Land is farmed to stream's edge	Livestock fencing; Restore riparian habitat; Filter strip installation

*Pasture renovation, providing an alternate water source, and grazing management are also possible management practices for this concern.

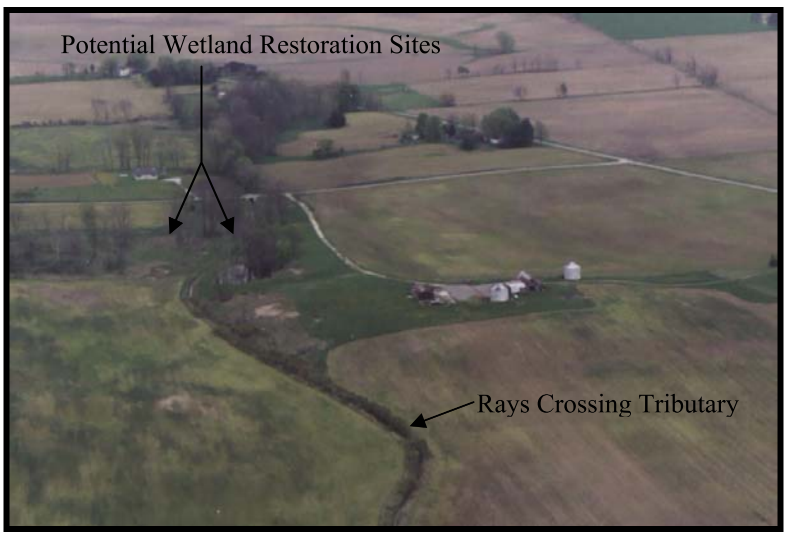


Figure 36. Sites A34 and A35 showing potential wetland restoration sites.

5.2.3 Manilla Branch Subwatershed

Much of the Manilla Branch Subwatershed was not captured in photos taken during the aerial tour. For this reason, it received more attention during the driving tour and will be discussed in the Windshield Tour Section. One area that might benefit from management application was identified during the aerial tour (Table 45). A stream crossing that appears to be routinely used to access pasture and crop land could benefit from bed stabilization to reduce sediment and sediment-attached pollutant loading to the Manilla Branch and the Little Blue River.

Table 45. The location where the application of a best management practice would improve water quality in nearby waterbodies as photographed during the aerial tour of the Manilla Branch Subwatershed. The issue of concern and practice that could be used to treat the concern is also listed.

Site	Concern	Management Practice
A40	Stream crossing appears to cause bed erosion	Stabilize stream bed

5.2.4 Cotton Run Subwatershed

Most photos taken of the Cotton Run Subwatershed were not detailed enough to discern individual problems. For this reason, additional time was spent in the Cotton Run Subwatershed during the windshield watershed tour. Cotton Run will be discussed in more detail in the Windshield Tour Section. The one site identified, Site A41, shows a typical practice in the Little Blue River Watershed: farming at or very near the stream's edge. Such situations are ideal for filter strip installation (Table 46).

Table 46. The location where the application of a best management practice would improve water quality in nearby waterbodies as photographed during the aerial tour of the Cotton Run Subwatershed. The issue of concern and practice that could be used to treat the concern is also listed.

Site	Concern	Management Practice
A41	Land is farmed to stream's edge	Filter strip installation

5.2.5 Middle Little Blue River Subwatershed

Thirteen areas of concern were documented during the aerial tour in the Middle Little Blue River Subwatershed (Table 47; Sites A43-A52, A100; Figure 29). The Town of Arlington has been a known contributor of pathogens as documented by the Rush County Health Department (Site A43; Figure 37). Historically, wastewater from Arlington passed through a series of septic systems and drainage tiles which then emptied directly into the Little Blue River from Arlington. During 2003 and 2004, the town will be completing sewer system connections to the Western Rush County Sewer District. This should reduce organic matter and pathogen loading to the Little Blue River. Many sites (A42, A44, A46, A47, A48, A49, A50, A51) in the Middle Little Blue River Subwatershed would benefit from riparian vegetation growth that will occur naturally if livestock are excluded and herbicides are not applied to the riparian areas. Channel instability has created bank sloughing and erosion near the toe of the stream bank at Site A45. Bank stabilization and the re-growth of natural riparian vegetation would improve this problem along the tributary to the Little Blue River, thereby reducing sediment and nutrient loading to the stream. Additionally, two sites would benefit from filter strip or grassed waterway installation (Figure 38; Site A52).

Table 47. List of locations where the application of best management practices would improve water quality in nearby waterbodies as photographed during the aerial tour of the Middle Little Blue Subwatershed. The issues of concern and practices that could be used to treat the concern(s) are also listed.

Site	Concern	Management Practice
A42	Natural vegetation has been removed	Shoreline stabilization; Allow natural vegetation growth
A43	Potential pollution source: Town of Arlington (Figure 37)	Urban BMPs
A44	Land appears to be heavily grazed*	Livestock fencing; Restore riparian habitat; Filter strip installation
A45	Stream banks are eroding	Restore riparian habitat; Stabilize stream banks
A46	Natural vegetation has been removed; Land appears to be heavily grazed*	Restore riparian habitat; Stabilize stream banks
A47	Natural vegetation has been removed	Restore riparian habitat; Stabilize stream banks
A48	Natural vegetation has been removed	Restore riparian habitat; Stabilize stream banks
A49	Natural vegetation has been removed	Restore riparian habitat; Stabilize stream banks
A50	Natural vegetation has been removed	Restore riparian habitat; Stabilize stream banks
A51	Land appears to be heavily grazed*; Land is farmed to stream's edge	Livestock fencing; Restore riparian habitat; Filter strip installation
A52	Rill and gully erosion is evident (Figure 38)	Grassed waterway installation; Filter strip installation
A53	Land is farmed to stream's edge	Filter strip installation
A100	Potential pollution source: Hog farm	On the ground investigation is needed to determine BMP

*Pasture renovation, providing an alternate water source, and grazing management are also possible management practices for this concern.

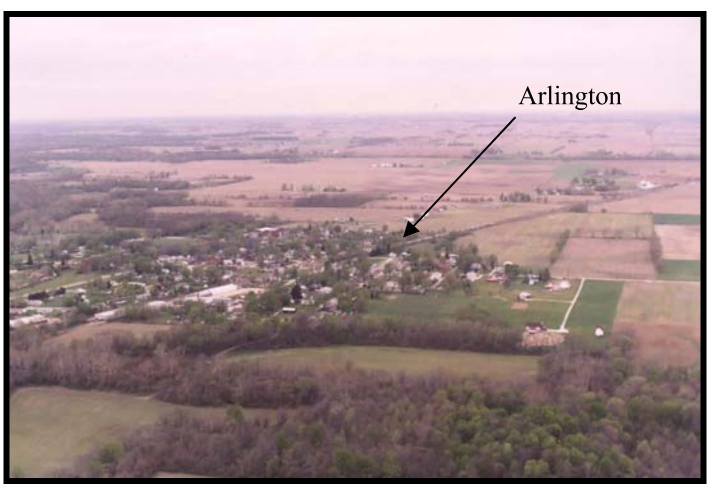


Figure 37. Site A43 showing the Town of Arlington which has historically been a source of organic matter and pathogens.

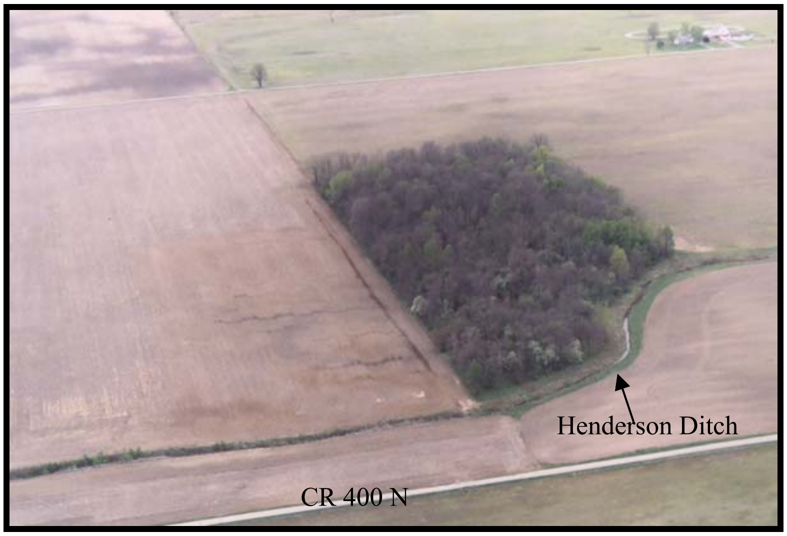


Figure 38. Site A52 showing the representative need for grassed waterways and filter strips along Henderson Ditch in the Middle Little Blue River Subwatershed.

5.2.6 Beaver Meadow Creek Subwatershed

Table 48 lists 16 sites in the Beaver Meadow Creek Subwatershed where land management activities could improve water quality (Table 48; Sites A54-A68, A99; Figure 29). Photos taken in the Beaver Meadow Creek Subwatershed document a practice that is typical of this subwatershed: farming at or very near the stream's edge as shown at Site A56 in Figure 39. Sites A56, A60, A61, A63, and A68 would benefit from the installation of filter strips. Site A62 offers potential for a wetland restoration project, which would expand water-holding capacity in the watershed and help slow erosion processes downstream. Multiple sites where livestock have grazed along the stream channel were identified during the aerial tour. Sites A54, A55, A57, A58, A59, A64, A65, and A66 appear to have been grazed or overgrazed; livestock should be excluded from the stream's riparian zone to preserve banks and prevent water contamination (Site A64; Figure 40). Two additional concerns in the Beaver Meadow Creek Subwatershed include streambank erosion due to farming near the stream's edge (Site A67) and potential nonpoint source pollution from confined animal feeding operation (Site A99).

Table 48. List of locations where the application of best management practices would improve water quality in nearby waterbodies as photographed during the aerial tour of the Beaver Meadow Creek Subwatershed. The issues of concern and practices that could be used to treat the concern(s) are also listed.

Site	Concern	Management Practice
A54	Land appears to be heavily grazed*	Livestock fencing; Restore riparian habitat; Filter strip installation
A55	Land appears to be heavily grazed*	Livestock fencing; Restore riparian habitat; Filter strip installation
A56	Land is farmed to stream's edge (Figure 39)	Filter strip installation
A57	Land appears to be heavily grazed*	Livestock fencing; Restore riparian habitat; Filter strip installation
A58	Land appears to be heavily grazed*	Livestock fencing; Restore riparian habitat; Filter strip installation
A59	Land appears to be heavily grazed*	Livestock fencing; Restore riparian habitat; Filter strip installation
A60	Land is farmed to stream's edge	Filter strip installation
A61	Land is farmed to stream's edge	Filter strip installation
A62	NA	Wetland restoration is possible
A63	Land is farmed to stream's edge	Filter strip installation
A64	Land appears to be heavily grazed* (Figure 40)	Livestock fencing; Restore riparian habitat; Filter strip installation
A65	Land appears to be heavily grazed*	Livestock fencing; Restore riparian habitat; Filter strip installation
A66	Land appears to be heavily grazed*	Livestock fencing; Restore riparian habitat; Filter strip installation
A67	Banks are eroding	Stabilize stream banks
A68	Land is farmed to stream's edge	Filter strip installation
A99	Potential pollution source: Hog farm	On the ground investigation is needed to determine BMP

*Pasture renovation, providing an alternate water source, and grazing management are also possible management practices for this concern.

Figure 39. Site A56 showing the need for filter strips along the mainstem of and tributaries to Beaver Meadow Creek.

Figure 40. Site A64 showing representative livestock grazing areas along the mainstem of Beaver Meadow Creek.

5.2.7 <u>Farmers Stream Subwatershed</u>

Photos taken of the Farmers Stream Subwatershed were not detailed enough to discern individual problems. For this reason, additional time was spent in the Farmers Stream Subwatershed during the windshield watershed tour. The Farmers Stream Subwatershed will be discussed in more detail in the Windshield Tour Section.

5.2.8 <u>Upper Little Blue River Subwatershed</u>

Ten areas of concern were documented during the aerial tour of the Upper Little Blue River Subwatershed (Table 49; Sites A69-77, A98; Figure29). Fairly severe bank compaction and riparian zone disturbance was evident at Site A73 where a dirt access road is in use (Figure 41;

Table 49). Continuous usage of this crossing could also cause streambed erosion and/or loading of sediment and sediment-attached nutrients to the Little Blue River. Constant stream bank disturbance due to livestock impacts the riparian area at the majority of the 10 sites including Sites A70, A71, A72, A74, A75, and A77. Although no livestock are evident in the Site A75 photo, stream banks and surrounding land appears to have been grazed (Figure 42). Livestock at Site A77 and multiple other sites throughout the subwatershed contribute to sediment, nutrient, and pathogen loading by trampling banks, depositing fecal matter, and resuspending sediments when traveling into and out of the stream (Figure 43). Livestock should be fenced away from streams and riparian areas to reduce sediment, nutrient, and pathogen loading to the Little Blue River. Two sites, A69 and A98, document the presence of confined animal feeding operations, while Site A76 identifies an area of streambank erosion.

Table 49. List of locations where the application of best management practices would improve water quality in nearby waterbodies as photographed during the aerial tour of the Upper Little Blue River Subwatershed. The issues of concern and practices that could be used to treat the concern(s) are also listed.

Site	Concern	Management Practice
A69	Potential pollution source: Hog farm	On the ground investigation is needed to determine BMP
A70	Natural vegetation has been removed	Restore riparian habitat; Stabilize stream banks
A71	Land appears to be heavily grazed*	Livestock fencing; Restore riparian habitat; Filter strip installation
A72	Land appears to be heavily grazed*	Livestock fencing; Restore riparian habitat; Filter strip installation
A73	Stream crossing (Figure 41)	Stabilize stream bed and bank with glacial stone
A74	Land appears to be heavily grazed*	Livestock fencing; Restore riparian habitat; Filter strip installation
A75	Natural vegetation has been disturbed; Land appears to be heavily grazed* (Figure 42)	Restore riparian habitat; Stabilize stream banks
A76	Banks are eroding	Stabilize stream banks; Restore riparian habitat
A77	Land appears to be heavily grazed* (Figure 43)	Livestock fencing; Restore riparian habitat; Filter strip installation
A98	Potential pollution source: Hog farm	On the ground investigation is needed to determine BMP

*Pasture renovation, providing an alternate water source, and grazing management are also possible management practices for this concern.

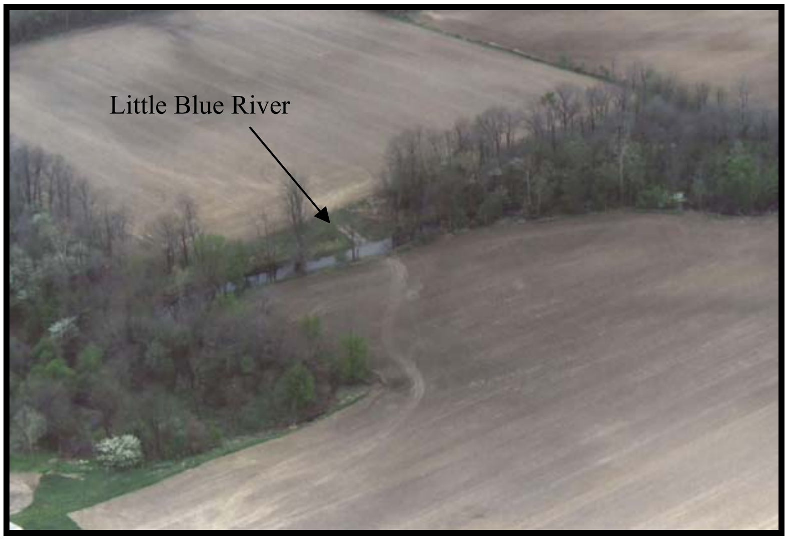


Figure 41. Site A73 showing a dirt access road across the Little Blue River in the Upper Little Blue River Subwatershed.

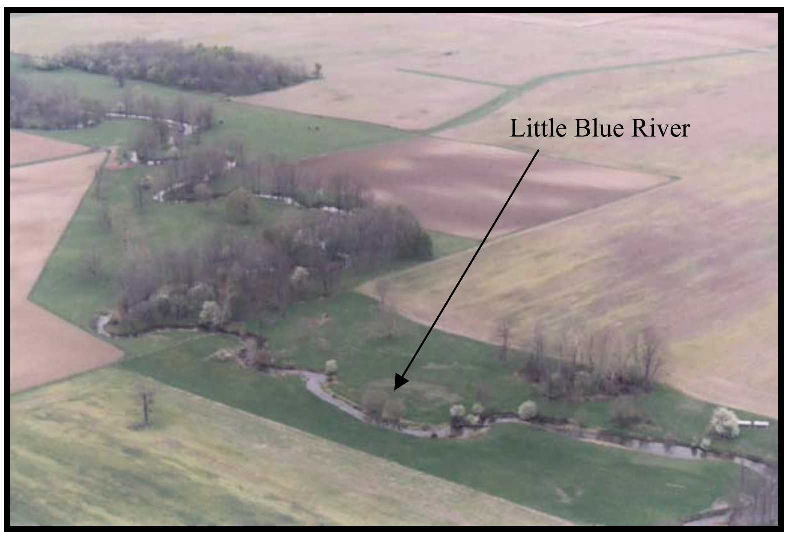


Figure 42. Site A75 showing the need for riparian restoration and bank stabilization due to livestock grazing along the mainstem of the Little Blue River.

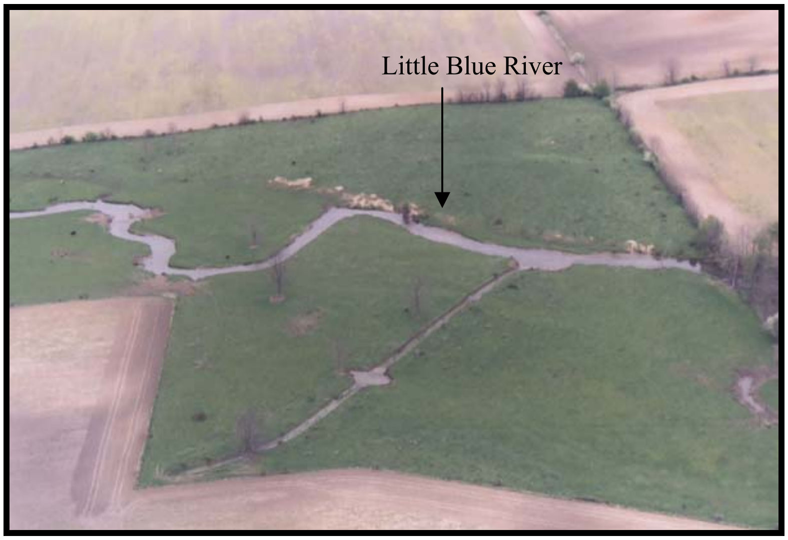


Figure 43. Site A77 showing grazed pastureland adjacent to the Little Blue River.

5.2.9 Little Gilson Creek Subwatershed

As was the case with photos of the Manilla Branch Subwatershed, aerial photos of the Little Gilson Creek Subwatershed also resulted in identification of only one area where BMPs may be appropriate (Table 50; Sites A78; Figure 29). The areas that were not photographed during the aerial tour received greater attention during the windshield survey. The land at the headwaters of the west branch of Little Gilson Creek appeared to have been overgrazed, and livestock should be excluded from the stream's riparian zone to preserve banks and prevent water contamination.

Table 50. The location where the application of a best management practice would improve water quality in nearby waterbodies as photographed during the aerial tour of the Little Gilson Creek Subwatershed. The issue of concern and practice that could be used to treat the concern is also listed.

Site	Concern	Management Practice
A78	Land appears to be heavily grazed*	Livestock fencing; Restore riparian habitat; Filter strip installation

*Pasture renovation, providing an alternate water source, and grazing management are also possible management practices for this concern.

5.2.10 Headwaters Subwatershed

Nineteen areas of concern were identified during the aerial tour of the Headwaters Subwatershed (Table 51; Sites A79-A97; Figure 29). Stream bank disturbance either due to production, livestock grazing, or other activities impacts the riparian area at 13 of the 19 sites. Livestock fencing, riparian vegetation planting and protection, and the usage of bank stabilization techniques could reduce sediment and nutrient loading to the Little Blue River. A potential wetland restoration site near the mainstem of the Little Blue River was also identified during the aerial tour (Site A88). Because the wetland is near the headwaters, it could store runoff during storms, preventing the large volumes of rapidly moving runoff from causing stream bank and bed erosion downstream. Shoreline restoration on a reservoir near the headwaters (Site A81) would be beneficial for the entire Little Blue River Watershed (Figure 44). Stabilizing the reservoir's shoreline would reduce sediment and nutrient loading to the Little Blue River during both high and low flow events. Three additional sites document the presence of potential pollution sources including a confined feeding operation (Site A92), the Town of Mays (Site A97), and a vehicle scrap yard (Site A96). A vehicle scrap yard was documented near the stream at the intersection of State Road 3 and U.S. Highway 40 (Figure 45). This study did not focus on possible scrap yard impacts on water quality, but the location of the scrap yard is noteworthy since leaking oil, grease, and other vehicle fluids can affect surface and groundwater quality.

Table 51. List of locations where the application of best management practices would improve water quality in nearby waterbodies as photographed during the aerial tour of the Headwaters Subwatershed. The issues of concern and practices that could be used to treat the concern(s) are also listed.

Site	Concern	Management Practice
A79	Banks are eroding	Stabilize stream banks; Restore riparian habitat
A80	Natural vegetation has been removed	Restore riparian habitat; Stabilize stream banks
A81	Natural vegetation has been removed (Figure 44)	Shoreline stabilization; Allow natural vegetation growth
A82	Land appears to be heavily grazed*	Livestock fencing; Restore riparian habitat; Filter strip installation
A83	Banks are eroding	Stabilize stream banks
A84	Banks are eroding	Stabilize stream banks; Restore riparian habitat
A85	Land is farmed to stream's edge	Filter strip installation
A86	Natural vegetation has been removed	Restore riparian habitat; Stabilize stream banks
A87	Land appears to be heavily grazed*	Livestock fencing; Restore riparian habitat; Filter strip installation
A88	NA	Wetland restoration is possible
A89	Natural vegetation has been removed	Restore riparian habitat; Stabilize stream banks
A90	Banks are eroding	Stabilize stream banks; Restore riparian habitat
A91	Natural vegetation has been removed	Shoreline stabilization; Allow natural vegetation growth
A92	Potential pollution source: Hog farm	On the ground investigation is needed to determine BMP
A93	Land appears to be heavily grazed*; Land is farmed to stream's edge	Livestock fencing; Restore riparian habitat; Filter strip installation
A94	Potential pollution source: Ponds adjacent to stream (thermal pollution)	On the ground investigation is needed to determine BMP
A95	Banks are eroding; Land is farmed to stream's edge	Stabilize stream banks; Restore riparian habitat
A96	Potential pollution source: Vehicle scrap yard (Figure 45)	On the ground investigation is needed to determine BMP
A97	Potential pollution source: Town of Mays	On the ground investigation is needed to determine BMP

*Pasture renovation, providing an alternate water source, and grazing management are also possible management practices for this concern.

Figure 44. Site A81 showing the need for shoreline stabilization and revegetation around a reservoir along the mainstem of the Little Blue River.

Figure 45. Vehicle scrap yard near the Little Blue River (Site A96).

5.3 WINDSHIELD TOUR

The windshield survey was conducted December 2, 2003 and entailed driving the watershed and assessing the streams where they crossed or were adjacent to roads. Kerry Brown, Shelby County SWCD District Administrator, Bill Harting, Shelby County NRCS District Conservationist, Todd Spegal, Shelby County SWCD Supervisor, Linda Mahan, Rush County SWCD District Administrator, and Curtis Knueven, Rush County NRCS District Conservationist participated in the tour. Particular areas of concern were examined more closely by stopping and walking areas within the public right-of-way. The need for BMP implementation was the most common observation made during the windshield tour of the Little Blue River Watershed. Table 52 lists all sites where BMP implementation or installation could benefit water quality. Site locations are displayed in Figure 29, while Figure 30 shows recommendations for water quality improvement locations. Photos for specific areas of concern appear in Figures 46-50.

Table 52. Lists of sites and corresponding BMPs compiled during the windshield survey of the Little Blue River Watershed.

Subwatershed	Site	Recommended Best Management Practice
Lower Little Blue River	W1	Bank Stabilization
Lower Little Blue River	W2	Bank Stabilization (Figure 46)
Lower Little Blue River	W3	Filter Strip Installation
Lower Little Blue River	W4	Filter Strip Installation
Lower Little Blue River	W5	Potential Point/Non-point Source of Pollution; Drainage from fenced feedlot
Lower Little Blue River	W6	Filter Strip Installation
Lower Little Blue River	W7	Filter Strip Installation
Lower Little Blue River	W8	Potential Wetland Restoration
Lower Little Blue River	W9	Filter Strip Installation
Lower Little Blue River	W10	Potential CRP
Lower Little Blue River	W11	Potential CRP
Lower Little Blue River	W12	Potential CRP
Lower Little Blue River	W13	Potential CRP
Lower Little Blue River	W14	Filter Strip Installation
Lower Little Blue River	W15	Bank Stabilization
Lower Little Blue River	W16	Filter Strip Installation
Lower Little Blue River	W17	Bank Stabilization
Lower Little Blue River	W18	Filter Strip Installation
Lower Little Blue River	W19	Potential Wetland Restoration
Lower Little Blue River	W20	Filter Strip Installation
Lower Little Blue River	W21	Potential Wetland Restoration
Lower Little Blue River	W22	Filter Strip Installation
Lower Little Blue River	W23	Bank Stabilization
Lower Little Blue River	W24	Filter Strip Installation
Lower Little Blue River	W25	Livestock Fencing*
Lower Little Blue River	W26	Livestock Fencing
Lower Little Blue River	W27	Livestock Fencing
Lower Little Blue River	W28	Filter Strip Installation
Lower Little Blue River	W29	Filter Strip Installation
Lower Little Blue River	W30	Livestock Fencing
Rays Crossing Tributary	W31	Filter Strip Installation
Manilla Branch	W32	Filter Strip Installation
Manilla Branch	W33	Filter Strip Installation
Manilla Branch	W34	Filter Strip Installation
Manilla Branch	W35	Filter Strip Installation
Manilla Branch	W36	Potential Point/Non-point Source of Pollution; Drainage from fenced feedlot
Cotton Run	W37	Filter Strip Installation
Middle Little Blue River	W38	Bank Stabilization
Middle Little Blue River	W39	Filter Strip Installation
Middle Little Blue River	W40	Filter Strip Installation

Subwatershed	Site	Recommended Best Management Practice
Middle Little Blue River	W41	Grassed Waterway Maintenance
Middle Little Blue River	W42	Potential Wetland Restoration
Middle Little Blue River	W43	Livestock Fencing
Middle Little Blue River	W44	Potential Wetland Restoration
Middle Little Blue River	W45	Filter Strip Installation
Middle Little Blue River	W46	Filter Strip Installation
Middle Little Blue River	W47	Widen Filter Strip/Filter Strip Maintenance
Middle Little Blue River	W48	Grassed Waterway Maintenance
Middle Little Blue River	W49	Widen Filter Strip/Filter Strip Maintenance
Middle Little Blue River	W50	Filter Strip Installation
Beaver Meadow Creek	W51	Filter Strip Installation
Beaver Meadow Creek	W52	Livestock Fencing
Beaver Meadow Creek	W53	Livestock Fencing
Beaver Meadow Creek	W54	Livestock Fencing
Beaver Meadow Creek	W55	Filter Strip Installation
Beaver Meadow Creek	W56	Filter Strip Installation
Beaver Meadow Creek	W57	Filter Strip Installation
Beaver Meadow Creek	W58	Filter Strip Installation
Beaver Meadow Creek	W59	Filter Strip Installation
Beaver Meadow Creek	W60	Filter Strip Installation
Beaver Meadow Creek	W61	Livestock Fencing
Beaver Meadow Creek	W62	Filter Strip Installation
Beaver Meadow Creek	W63	Filter Strip Installation
Beaver Meadow Creek	W64	Filter Strip Installation
Farmers Stream	W65	Grassed Waterway Installation
Farmers Stream	W66	Filter Strip Installation
Farmers Stream	W67	Grassed Waterway Installation
Upper Little Blue River	W68	Grassed Waterway Maintenance
Upper Little Blue River	W69	Streambed Stabilization
Upper Little Blue River	W70	Livestock Fencing
Upper Little Blue River	W71	Livestock Fencing
Upper Little Blue River	W72	Streambed Stabilization
Upper Little Blue River	W73	Filter Strip Installation
Upper Little Blue River	W74	Livestock Fencing
Little Gilson Creek	W75	Bank Stabilization
Little Gilson Creek	W76	Filter Strip Installation
Little Gilson Creek	W77	Livestock Fencing
Little Gilson Creek	W78	Filter Strip Installation
Headwaters	W79	Livestock Fencing
Headwaters	W80	Potential Wetland Restoration
Headwaters	W81	Livestock Fencing
Headwaters	W82	Filter Strip Installation
Headwaters	W83	Livestock Fencing (Figure 47)
Headwaters	W84	Livestock Fencing

Subwatershed	Site	Recommended Best Management Practice
Headwaters	W85	Widen Filter Strip/Filter Strip Maintenance
Headwaters	W86	Widen Filter Strip/Filter Strip Maintenance
Headwaters	W87	Filter Strip Installation
Headwaters	W88	Widen Filter Strip/Filter Strip Maintenance
Headwaters	W89	Filter Strip Installation
Headwaters	W90	Widen Filter Strip/Filter Strip Maintenance
Headwaters	W91	Widen Filter Strip/Filter Strip Maintenance
Headwaters	W92	Livestock Fencing
Headwaters	W93	Livestock Fencing
Headwaters	W94	Widen Filter Strip/Filter Strip Maintenance (Figure 48)
Headwaters	W95	Filter Strip Installation
Headwaters	W96	Filter Strip Installation
Headwaters	W97	Widen Filter Strip/Filter Strip Maintenance
Headwaters	W98	Potential Wetland Restoration
Headwaters	W99	Widen Filter Strip/Filter Strip Maintenance
Headwaters	W100	Livestock Fencing
Headwaters	W101	Potential Wetland Restoration (Figures 49 and 50)
Headwaters	W102	Potential Wetland Restoration
Lower Little Blue River	W103	Livestock Fencing
Middle Little Blue River	W104	Livestock Fencing

*Pasture renovation, providing an alternate water source, and grazing management are also possible management practices for this concern.

Figure 46. Site W2 taken during the windshield survey showing unstable banks and the need for increased riparian width at the upstream end of the proposed Shelbyville parks facility.

Figure 47. Site W83 taken during the windshield survey which displays the need for livestock fencing and subsequent bank stabilization and filter strip installation. The landowner has made efforts to retard bank sloughing and prevent the Little Blue River from eroding more bank material.

Figure 48. Warm season grasses should be planted around the pond at Site W94 to reduce shoreline erosion and provide habitat and shading for the pond's biota.

Figure 49. Old Soil Conservation Service structure installed to reduce gully erosion at Site W100.

Figure 50. Site W100 showing the livestock pasture through which the headwaters of the Little Blue River flows. A grassed waterway should be installed and cattle fenced from the waterway to prevent nutrient cycling to the stream.

6.0 WATER QUALITY ASSESSMENT

6.1 INTRODUCTION

The water quality assessment portion of the Little Blue River Diagnostic Study consisted of water chemistry sampling during base flow and a storm runoff event, a macroinvertebrate community assessment, and a habitat assessment. Sampling was conducted at ten sites in the Little Blue River Watershed and one reference site outside of the watershed. The water quality assessment provides information on water quality and aquatic habitat health. The data also assist in guiding the prioritization of management actions and directing those actions toward the most critical areas.

6.1.1 Sampling Locations

Ten stream sites were strategically chosen throughout the Little Blue River Watershed (Table 53; Figure 51). These sites were selected based on accessibility and input from the Shelby County and Rush County SWCDs. Sample sites correspond with the seven major tributaries located throughout the watershed. Project biologists located three additional sample sites along the mainstem of the Little Blue River allowing for comparison between the upper, middle, and lower portions of the river. The water quality assessment protocol also includes sampling at a reference site for comparative purposes. An ideal reference site would lie in a relatively undisturbed watershed and would meet all criteria listed in Table 54. However, because of extensive human activities throughout the study watershed, a reference site meeting all criteria in Table 54 could not be located.

Table 53. Detailed sampling location information for the Little Blue River Watershed sampling sites.

Site #	Stream Name	Subwatershed	Road Location	Latitude	Longitude
1	Little Blue River	Lower Little Blue River	Kennedy Park	N39° 31.52’	W85° 45.82’
2	Rays Crossing Tributary	Rays Crossing	Union Road	N39° 33.63’	W85°42.32’
3	Manilla Branch	Manilla Branch	CR 775 E	N39° 33.06’	W85° 38.19’
4	Cotton Run	Cotton Run	CR 1000 W	N39° 36.13’	W85° 37.92’
5	Little Blue River	Middle Little Blue River	Base Road	N39° 37.02’	W85° 37.22’
6	Beaver Meadow Creek	Beaver Meadow Creek	CR 100 N	N39° 37.52’	W85° 36.58’
7	Farmers Stream	Farmers Stream	Offutts Bridge Road	N39° 39.98’	W85° 32.67’
8	Little Blue River	Upper Little Blue River	Offutts Bridge Road	N39° 39.62’	W85° 32.37’
9	Little Gilson Creek	Little Gilson Creek	Rushville Road	N39° 43.38’	W85° 29.32’
10	Little Blue River	Headwaters	Rushville Road	N39° 43.16’	W85° 29.15’
Ref	Conn’s Creek	Reference	CR 900 W	N39° 32.56’	W85° 36.72’

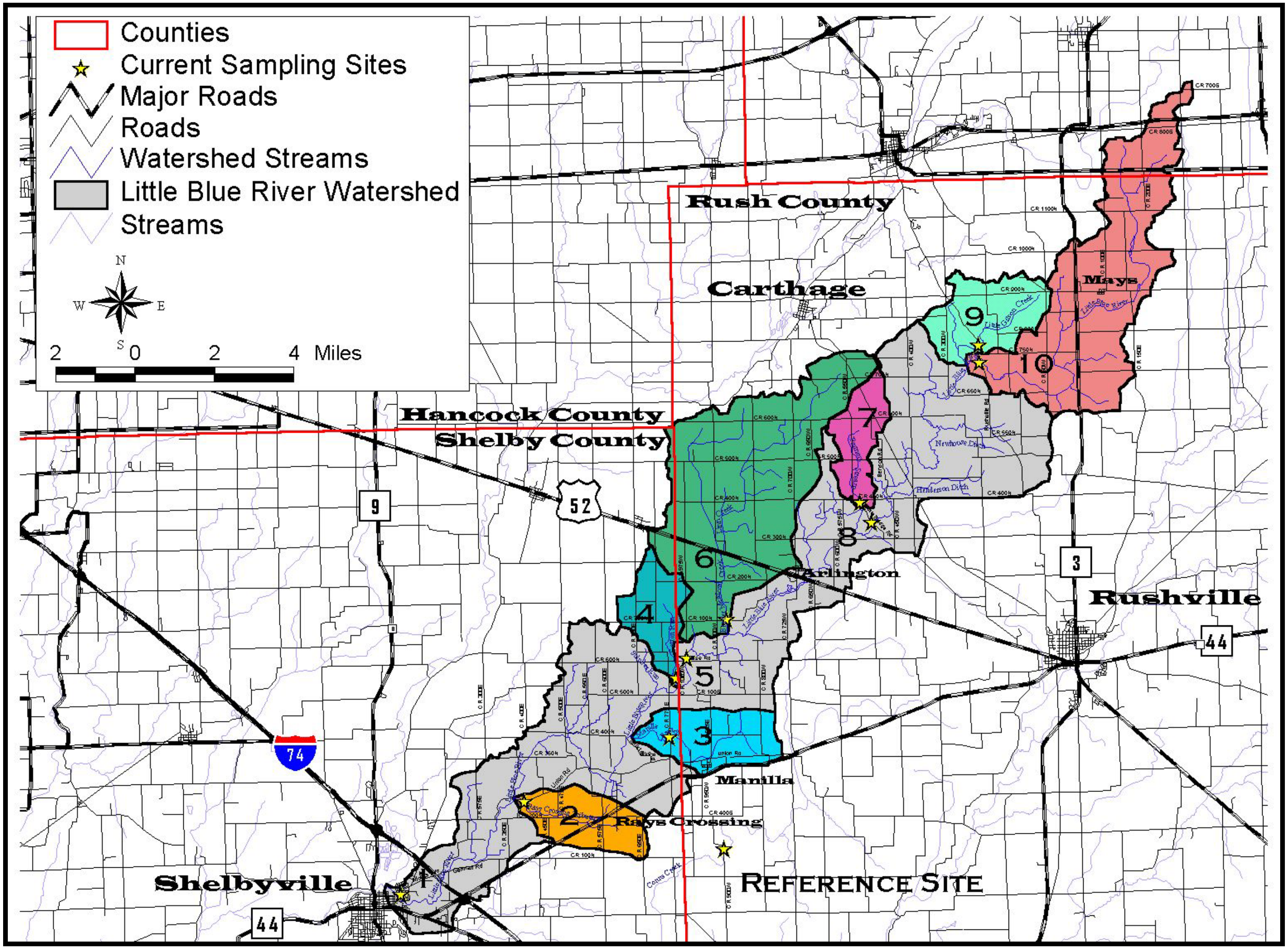


Figure 51. Sampling locations in the Little Blue River Watershed. Source: See Appendix A.

Table 54. Minimum criteria for stream reference sites.

Example Criteria for Reference Sites (must meet all criteria)
• pH>=6; if blackwater stream, then pH<=6 and DOC>8mg/l • Dissolved Oxygen>=4 mg/l • Nitrate<=16.5 mg/l • Urban land use<=20% of catchment area • Forest land use>=25% of catchment area • Instream habitat rating optimal or suboptimal • Riparian buffer width>=15 m • No channelization • No point source discharges

Source: Plafkin et al., 1999.

State personnel have suggested two streams that offer potential for use as reference sites: Stoney Creek near Muncie, Indiana and Otter Creek near Terre Haute, Indiana. However, neither of these two streams is located within the same ecoregion as the study area. Because of their location within different ecoregions, the relevance of comparing Stoney or Otter Creeks with the Little Blue River is limited.

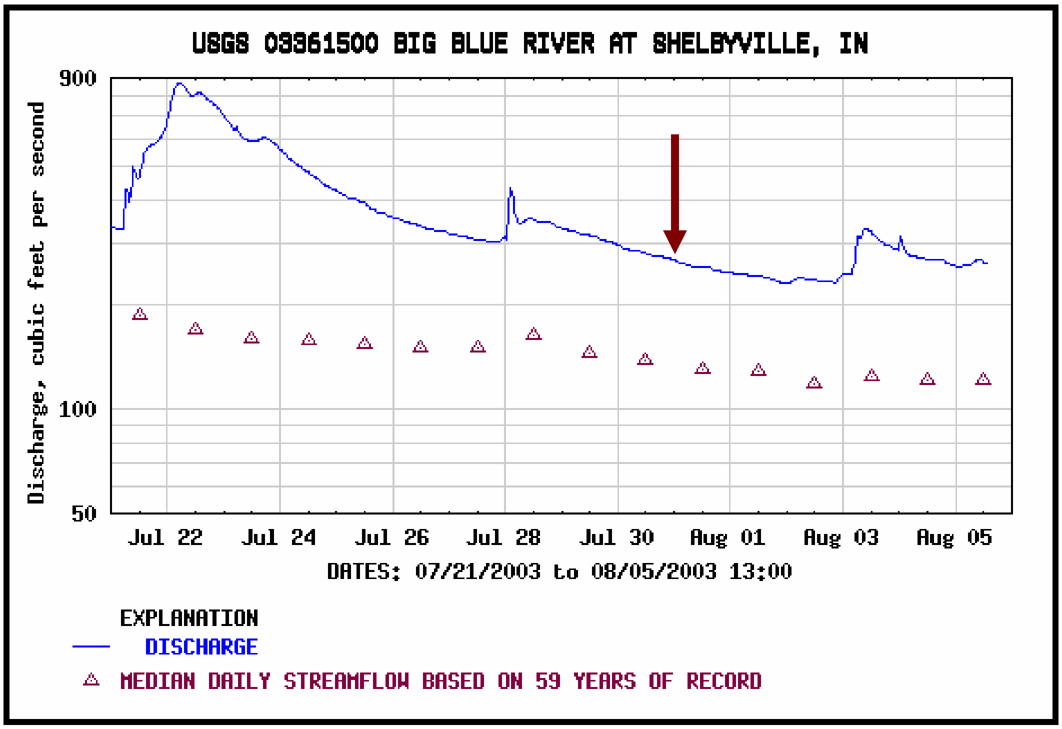
IDEM sampled multiple locations throughout the East Fork White River Basin during a 1997 fish community survey (Dufour, 2000). During the survey, IDEM sampled three streams in watersheds adjacent to the Little Blue River, the Big Blue River, Sugar Creek, and Conn's Creek. Sugar Creek at State Road 44 possessed high QHEI and IBI scores, 77 and 54, respectively. However, this site has two problems: 1) at base flow the stream is physically impassible by wading, so sampling this site during storm flow could be difficult, even hazardous; and 2) water chemistry and macroinvertebrate data collected at this site may not be comparable to data collected in the Little Blue River watershed due to differences in stream and watershed size. Conn's Creek at County Road 900 West received a QHEI score of 69, while the fish community scored an IBI score of 40. An elevated proportion of individuals with DELT anomalies and a low number of individuals limited the IBI score; however, a high number of species, darter species, and sensitive species and a low number of tolerant species indicate that the stream is capable of supporting a sensitive, diverse community. Conn's Creek may not be the highest quality stream in the East Fork White River Basin, but is representative of "high" quality streams for this watershed. As Simon noted during development of the Eastern Corn Belt Plains IBI, few natural areas remain within this ecoregion (1998). Simon noted that extensive row crop agriculture and anthropogenic factors limited the quality of habitat observed throughout the ecoregion resulting in lowered biological integrity. While this site does not have an IBI score in the 50s, JFNew and IDNR Division of Soil Conservation Staff determined that this site serves as a good reference site based on the level of human disturbance in the region.

6.2 WATER CHEMISTRY ASSESSMENT

6.2.1 Water Chemistry Methods

The LARE sampling protocol requires assessing water quality of each stream site once during base flow and once during storm flow. Base flow sampling provides an understanding of the typical conditions in the streams. Following storm events, increased overland flow results in increased erosion of soil and nutrients from the land. Stream concentrations of nutrients and sediment are typically higher following storm events. Storm event sampling provides a "worst case" scenario picture of watershed pollutant loading.

Base flow samples were collected July 30-31, 2003 following a period of little precipitation. While river stage at the Big Blue River was slightly higher than historic median daily stream flow (Figure 52), the hydrograph shows that much of the volume from a recent rain event had already flowed past the gauging station downstream of the Little Blue River's confluence with the Big Blue River. This suggests that flow conditions had returned to normal. Base flow sampling provides an understanding of typical conditions in streams. However, it is important to note that even though these water quality samples provide insight into the characteristics of the streams at the particular time of sampling, it is difficult to extrapolate these results to other times of the year and different conditions.

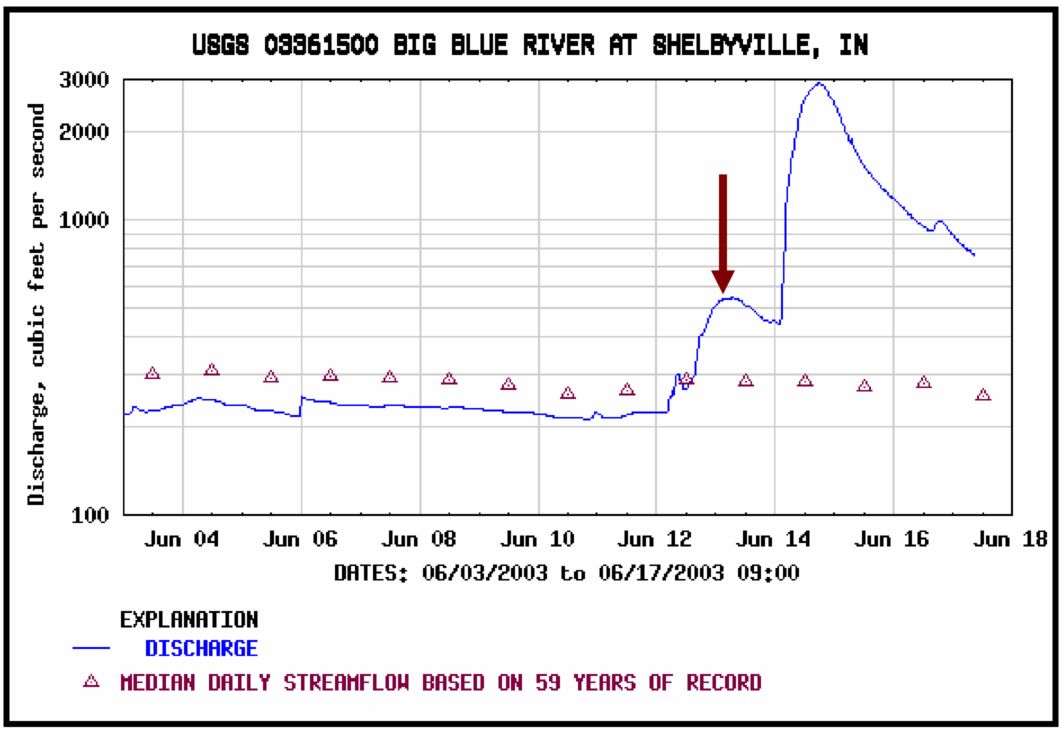


Source: USGS Real-time data, 2003.

Figure 52. Discharge in the Big Blue River immediately downstream of the confluence with the Little Blue River. The arrow marks the discharge in the Big Blue River on the base flow sampling date.

Base flow samples for the Middle Little Blue River (Site 5) were collected on October 31, 2003. Project biologists collected samples for this site from a minor tributary, which is non-comparable to the Little Blue River sampling sites. The error was observed after data analysis occurred; therefore, a second sampling base flow sampling trip was scheduled. Sampling occurred following a period of 0.25 inches of rainfall over a five day period and the Big Blue River hydrograph was below the median daily stream flow; therefore, this sampling data is representative of base flow conditions. It is important to remember that although samples collected and analyzed on this date are representative of base flow conditions within the stream, they may not be directly comparable to samples collected during July at the remaining sites.

Storm event samples were collected June 13, 2003 following a 24-hour, 1.75 inch rain event. River stage exceeded the historic median daily storm flow (Figure 53). Discharge at the Big Blue River gauging station exceeded the historical median discharge, peaking at nearly 10 times the historical median. Based on the hydrograph, the June 13 sampling effort documented storm flow conditions in the watershed streams. Following storm events, the increased overland water flow results in increased erosion of soil and nutrients from the land. In addition, precipitation washes pollutants from hardscape in the watershed. Thus, stream concentrations of nutrients and sediment are typically higher following storm events. In essence, storm sampling presents a "worst case" picture of watershed pollutant loading.



Source: USGS Real-time data, 2003.

Figure 53. Discharge in the Big Blue River immediately downstream of the confluence with the Little Blue River. The arrow marks the discharge in the Big Blue River on the storm flow sampling date. Discharge on the sampling date exceeded the 59-year median stream flow.

Base flow and stormwater runoff sampling included measurements of physical, chemical, and bacteriological parameters. Conductivity, temperature, and dissolved oxygen were measured *in situ* at each stream site during base flow with a YSI Model 85 meter and during storm flow with a YSI Model 55. (Conductivity was measured during base flow sampling only.) Water velocity was measured using a Marsh-McBirney Flo-Mate current meter. Cross-sectional areas of the stream channel at each site were measured and discharge calculated by multiplying water velocity by the cross-sectional areas. In addition, water samples were collected from just below the water surface using a cup sampler and analyzed for the following parameters:

- pH
- alkalinity
- total phosphorus (TP)
- soluble reactive phosphorus (SRP)
- nitrate-nitrogen (NO_3-N)
- ammonia-nitrogen (NH_3-N)
- total Kjeldahl nitrogen (TKN)
- total suspended solids (TSS)
- turbidity
- *E. coli* bacteria

Following collection, samples were stored in an ice chest until analysis in the Indiana University School of Public and Environmental Affairs (IUSPEA) laboratory in Bloomington, Indiana. The *E. coli* samples were taken to Sherry Labs in Columbus for analysis. All sampling techniques and laboratory analysis methods were performed in accordance with procedures in *Standard Methods for the Examination of Water and Wastewater, 20th Edition* (APHA, 1998).

The comprehensive evaluation of streams requires collecting data on the different water quality parameters listed above. A brief description of each of the parameters follows:

Temperature Temperature can determine the form, solubility, and toxicity of a broad range of aqueous compounds. Likewise, water temperature regulates the species composition and activity of life associated with the aquatic environment. Since essentially all aquatic organisms are cold-blooded, the temperature of the water regulates their metabolism and ability to survive and reproduce effectively (USEPA, 1976). The Indiana Administrative Code (327 IAC 2-1-6) sets maximum temperature limits to protect aquatic life for Indiana streams. For example, temperatures during the months of June and July should not exceed 90°F (23.7°C) by more than 3°F (1.7°C). The code also states that the "maximum temperature rise at any time or place… shall not exceed 5°F (2.8°C) in streams…"

Dissolved Oxygen (DO) DO is the dissolved gaseous form of oxygen. It is essential for respiration of fish and other aquatic organisms. Fish need water to possess a DO concentration of at least 3-5 mg/l of DO. Coldwater fish such as trout generally require higher concentrations of DO than warmwater fish such as bass or bluegill. The IAC sets minimum DO concentrations at 5 mg/1 for warmwater fish. DO enters water by diffusion from the atmosphere and as a byproduct of photosynthesis by algae and plants. Excessive algae growth can over-saturate (greater than 100% saturation) the water with DO. Waterbodies with large populations of algae and macrophytes often exhibit supersaturation due to the high levels of photosynthesis. Dissolved oxygen is consumed by respiration of aquatic organisms, such as fish, and during bacterial decomposition of plant and animal matter.

Conductivity Conductivity is a measure of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions: on their total concentration, mobility, and valence (APHA, 1998). During low discharge, conductivity is higher than it is following a storm water runoff because the water moves more slowly across or through ion containing soils and substrates during base flow. Carbonates and other charged particles (ions) dissolve into the slow-moving water, thereby increasing conductivity levels.

Rather than setting a conductivity standard, the Indiana Administrative Code sets a standard for dissolved solids (750 mg/l). Multiplying a dissolved solids concentration by a conversion factor of 0.55 to 0.75 μmhos per mg/l of dissolved solids roughly converts a dissolved solids concentration to specific conductance (Allan, 1995). Thus converting the IAC dissolved solids concentration standard to specific conductance by multiplying 750 mg/l by 0.55 to 0.75 μmhos per mg/l yields a specific conductance range of approximately 1000 to 1350 μmhos.

pH The pH of stream water describes the concentration of acidic ions (specifically H^+) present in the water. The pH also determines the form, solubility, and toxicity of a wide range of other aqueous compounds. The IAC establishes a range of 6-9 pH units for the protection of aquatic life.

Alkalinity Alkalinity is a measure of the acid-neutralizing (or buffering) capacity of water. Certain substances in water, like carbonates, bicarbonates, and sulfates can cause the water to resist changes in pH. A lower alkalinity indicates a lower buffering capacity or a decreased ability to resist changes in pH. During base flow conditions, alkalinity is usually high because the water picks up carbonates from the bedrock. Alkalinity measurements are usually lower during storm flow conditions because buffering compounds are diluted by rainwater and the runoff water moves across carbonate-containing bedrock materials so quickly that little carbonate is dissolved to add additional buffering capacity.

Turbidity Turbidity (measured in Nephelometric Turbidity Units or NTUs) is a measure of water coloration and particles suspended in the water itself. It is generally related to suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. According to the Hoosier Riverwatch, the average turbidity of an Indiana stream is 11 NTU with a typical range of 4.5-17.5 NTU (White, unpublished data). Turbidity measurements >20 NTU have been found to cause undesirable changes in aquatic life (Walker, 1978). The U.S. Environmental Protection Agency developed recommended water quality criteria as part work to establish numeric criteria for nutrients on an ecoregion basis. Recommended turbidity concentrations for the Central Corn Belt Plains, in which the Little Blue River lies, are 9.89 NTUs (USEPA, 2000).

Nitrogen Nitrogen is an essential plant nutrient found in fertilizers, human and animal wastes, yard waste, and the air. About 80% of the air we breathe is nitrogen gas. Nitrogen gas diffuses into water where it can be "fixed", or converted, by blue-green algae to ammonia for their use. Nitrogen can also enter lakes and streams as inorganic nitrogen and ammonia. Because of this, there is an abundant supply of available nitrogen to aquatic systems. The three common forms of nitrogen are:

Nitrate-nitrogen (NO_3-N) Nitrate is an oxidized form of dissolved nitrogen that is converted to ammonia by algae. It is found is streams and runoff when dissolved oxygen is present, usually in the surface waters. Ammonia applied to farmland is rapidly oxidized or converted to nitrate and usually enters surface and groundwater as nitrate. The Ohio EPA (1999) found that the median nitrate-nitrogen concentration in wadeable streams classified as warmwater habitat (WWH) was 1.0 mg/l. Warmwater habitat refers to those streams which possess minor modifications and little human influence, like the mainstem of the Little Blue River. These streams, such as the mainstem of the Little Blue River, typically support communities with healthy, diverse warmwater fauna. The Ohio EPA (1999) found that the median nitrate-nitrogen concentration in wadeable streams classified as modified warmwater habitat (MWH) was 1.6 mg/1. Modified warmwater habitat was defined as: the aquatic life use assigned to streams that have irretrievable, extensive, man-induced modification that precludes attainment of the warmwater habitat use designation; such streams, like the Little Blue River tributaries, are characterized by species that are tolerant of poor chemical quality (fluctuating dissolved oxygen) and habitat conditions (siltation, habitat amplification) that often occur in modified streams (Ohio EPA, 1999). The U.S. Environmental Protection Agency developed recommended nitrate-nitrogen criterion as part of work to establish numeric criteria for nutrients on an ecoregion basis. The recommended nitrate-nitrogen concentration for the Central Corn Belt Plains, in which the Little Blue River lies, is 0.63 mg/l (USEPA, 2000). Nitrate-nitrogen concentrations exceeding 10 mg/1 in drinking water are considered hazardous to human health (Indiana Administrative Code IAC 2-1-6).

Ammonia-nitrogen (NH_3-N) Ammonia-nitrogen is a form of dissolved nitrogen that is the preferred form for algae use. Bacteria produce ammonia as they decompose dead plant and animal matter. Ammonia is the reduced form of nitrogen and is found in water where dissolved oxygen is lacking. Important sources of ammonia include fertilizers and animal manure. Both temperature and pH govern the toxicity of ammonia for aquatic life. According to the IAC, maximum ionized ammonia concentrations for the study streams should not exceed approximately 1.94 to 7.12 mg/1, depending on the water's pH and temperature.

Organic Nitrogen Organic nitrogen includes nitrogen found in plant and animal materials. It may be in dissolved or particulate form. In the analytical procedures, total Kjeldahl nitrogen (TKN) was analyzed. Organic nitrogen is TKN minus ammonia. The U.S. Environmental Protection Agency developed TKN crierion as part work to establish numeric criteria for nutrients on an ecoregion basis. The recommended total Kjeldahl nitrogen concentration for the Central Corn Belt Plains, in which the Little Blue River lies, is 0.591 mg/l (USEPA, 2000).

Phosphorus Phosphorus is an essential plant nutrient and the one that most often controls aquatic plant (algae and macrophyte) growth. It is found in fertilizers, human and animal wastes, and yard waste. There are few natural sources of phosphorus to streams other than that which is attached to soil particles; there is no atmospheric (vapor) form of phosphorus. For this reason, phosphorus is often a ***limiting nutrient*** in aquatic systems. This means that the relative scarcity of phosphorus may limit the ultimate growth and production of algae and rooted aquatic plants. Management efforts often focus on reducing phosphorus inputs to receiving waterways because: (a) it can be managed and (b) reducing phosphorus can reduce algae production. Two common forms of phosphorus are:

Soluble reactive phosphorus (SRP) SRP is dissolved phosphorus readily usable by algae. SRP is often found in very low concentrations in phosphorus-limited systems where the phosphorus is tied up in the algae themselves. Because phosphorus is cycled so rapidly through biota, SRP concentrations as low as 0.005 mg/l are enough to maintain eutrophic or highly productive conditions in lake systems (Correll, 1998). Sources of SRP include fertilizers, animal wastes, and septic systems.

Total phosphorus (TP) TP includes dissolved and particulate phosphorus. TP concentrations greater than 0.03 mg/1 (or 30µg/1) can cause algal blooms in lake systems. In stream systems, Dodd et al., 1998 suggests that streams with a total phosphorus concentration greater than 0.075 mg/l are typically characterized as productive or eutrophic. TP is often a problem in agricultural watersheds because TP concentrations required for eutrophication control are as much as an order of magnitude lower than those typically measured in soils used to grow crops (0.2-0.3 mg/l). The Ohio EPA (1999) found that the median TP concentration in wadeable streams that support WWM for fish was 0.10 mg/l, while wadeable streams that support MWH for fish was 0.28 mg/1. The U.S. Environmental Protection Agency recommended TP criterion for the Central Corn Belt Plains, in which the Little Blue River lies, is 0.076 mg/l (USEPA, 2000).

Total Suspended Solids (TSS) A TSS measurement quantifies all particles suspended in stream water. Closely related to turbidity, this parameter quantifies sediment particles and other solid compounds typically found in stream water. In general, the concentration of suspended solids is greater during high flow events due to increased overland flow. The increased overland flow erodes and carries more soil and other particulates to the stream. The State of Indiana does not have a TSS standard. In general, TSS concentrations greater than 80 mg/1 have been found to be deleterious to aquatic life (Waters, 1995).

***E. coli* Bacteria** *E. coli* is one member of a group of bacteria that comprise the fecal coliform bacteria and is used as an indicator organism to identify the potential presence of pathogenic organisms in a water sample. Pathogenic organisms can present a threat to human health by causing a variety of serious diseases, including infectious hepatitis, typhoid, gastroenteritis, and other gastrointestinal illnesses. *E. coli* can come from the feces of any warm-blooded animal. Wildlife, livestock, and/or domestic animal defecation, manure fertilizers, previously contaminated sediments, and failing or improperly sited septic systems are common sources of the bacteria. The IAC sets the maximum standard at 235 colonies/100 ml in any one sample within a 30-day period.

6.2.2 Water Chemistry Results and Discussion

Introduction

There are two useful ways to report water quality data in flowing water. Concentrations describe the mass of a particular material contained in a unit of water, for example, milligrams of phosphorus per liter (mg/l). Mass loading (in units of kilograms per day) on the other hand describes the mass of a particular material being carried per unit of time. For example, a high concentration of phosphorus in a stream with very little flow will deliver a smaller total amount of phosphorus to the receiving waterway than will a stream with a low concentration of phosphorus but a high flow of water. It is the total amount (mass) of phosphorus, solids, and bacteria actually delivered from the watershed that is most important when considering the effects of these materials downstream. Because consideration of concentration and mass loading data is important, the following three sections will discuss 1) physical parameter concentrations, 2) chemical and bacterial parameter concentrations, and 3) chemical and sediment parameter mass loading.

Physical Concentrations and Characteristics

Physical parameter results measured during base and storm flow sampling are presented in Table 55. Stream discharge measured during base and storm flow conditions are shown in Figure 54. Each physical parameter is addressed in the following discussion.

Table 55. Physical parameter data collected during stream chemistry sampling events in the Little Blue River Watershed on June 13, July 30, and July 31, 2003. Shaded squares indicate those samples that were in violation of Indiana state standards (■) or recommended target values (□; USEPA, 2000).

Site	Date	Timing	Flow (cfs)	Temp (°C)	DO (mg/l)	DO Sat (%)	Cond (µmhos)	pH	Alk (mg/l)	Turb (NTU)
1	7/30/03	Base	31.5	23.0	10.3	112.3	608	8.2	269	2.5
	6/13/03	Storm	122.4	19.4	8.0	87.8	*	8.2	221	11.0
2	7/31/03	Base	0.16	19.0	7.8	85.0	619	7.9	292	2.4
	6/13/03	Storm	13.2	16.5	8.6	87.6	*	7.8	169	29.0
3	7/31/03	Base	0.8	19.2	8.6	93.0	635	8.0	278	1.3
	6/13/03	Storm	5.0	16.4	10.0	101.6	*	8.0	228	1.4
4	7/31/03	Base	0.03	20.1	9.3	102.0	612	8.0	271	1.7
	6/13/03	Storm	3.6	17.0	9.1	93.4	*	8.2	215	3.1
5	10/31/03	Base	21.6	13.0	9.9	94.3	470	8.2	286	0.9
	6/13/03	Storm	62.7	19.8	8.0	87.9	*	8.2	240	10.0
6	7/31/03	Base	4.4	20.6	10.1	112.0	610	8.0	275	1.2
	6/13/03	Storm	11.6	18.8	8.7	93.6	*	8.1	232	4.8
7	7/31/03	Base	6.3	22.0	9.2	105.0	665	8.2	282	0.8
	6/13/03	Storm	1.6	18.5	9.5	101.0	*	8.3	251	1.6
8	7/30/03	Base	13.5	24.6	9.6	115	632	8.3	263	3.0
	6/13/03	Storm	41.6	20.9	8.8	98.7	*	8.2	222	19.0
9	7/30/03	Base	3.3	21.9	12.8	148.2	644	8.0	245	1.6
	6/13/03	Storm	2.4	18.7	11.6	124.2	*	8.1	223	1.7
10	7/30/03	Base	5.2	24.7	10.4	121.0	632	8.3	256	3.1
	6/13/03	Storm	15.8	20.1	8.1	89.7	*	8.0	247	16.0
Ref	7/30/03	Base	12.6	23.8	8.2	97.0	645	8.2	267	2.8
	6/13/03	Storm	77.6	18.3	8.2	87.2	*	7.9	198	29.0

* = Conductivity was only sampled during the base flow event.

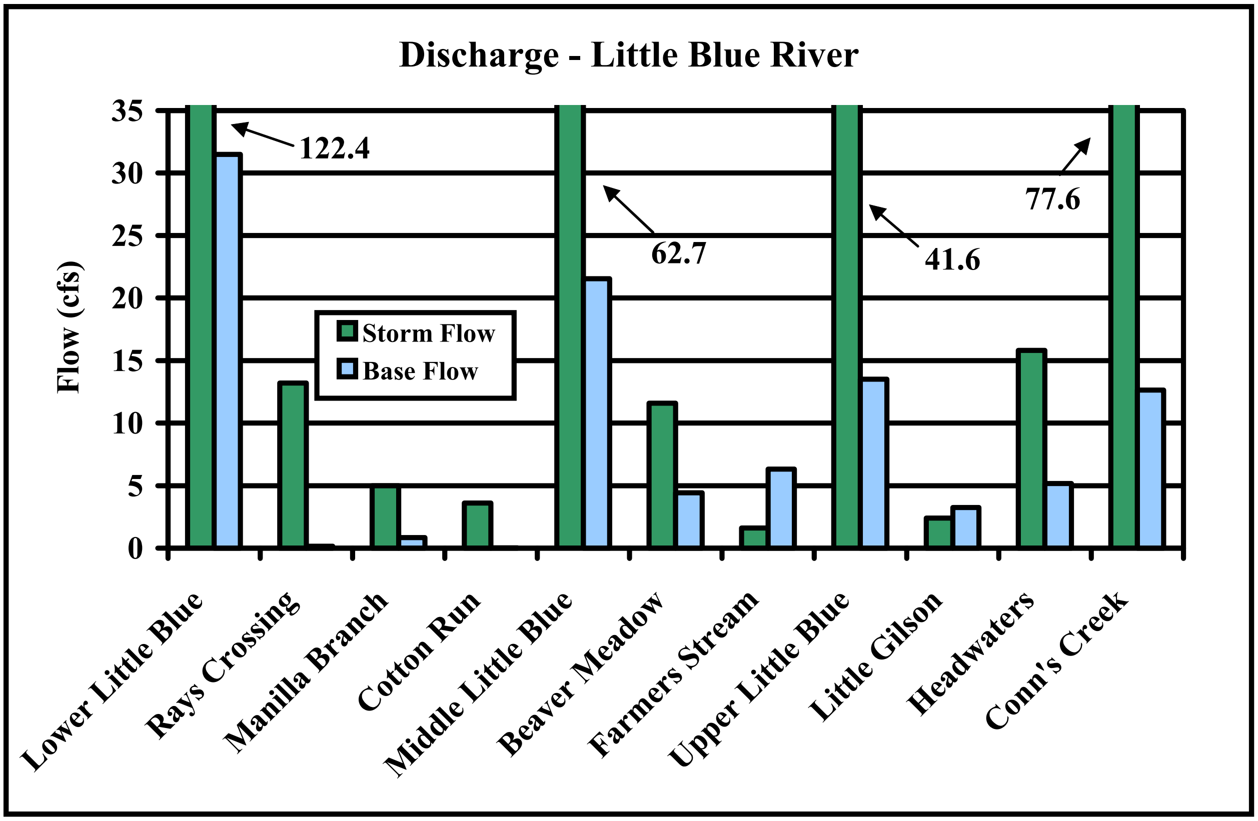


Figure 54. Discharge measurements during base flow and storm flow sampling of Little Blue River Watershed streams.

Water temperature varied with sample timing. As expected, the Little Blue River and its tributaries were warmer in July than in June. During storm flow sampling, the Little Blue River and its tributaries exhibited a water temperature range of 66.2°F (19.0°C) at Rays Crossing (Site 2) to 76.5°F (24.7°C) at the Headwaters (Site 10); during base flow the temperature range was 61.5°F (16.4°C) at Manilla Branch (Site 3) to 69.6°F (20.9°C) at the Upper Little Blue River (Site 8). The Middle Little Blue River (Site 5) exhibited the lowest water temperature (55.4°F or 13.0°C); however, this sample was collected during November. Water temperatures in November are typically lower than those measured in June and July. All temperatures were within ranges suitable for aquatic life. In general, mainstem water temperatures were higher than tributary temperatures. Those tributaries with the coolest temperatures were Rays Crossing (Site 2), Manilla Branch (Site 3), and Cotton Run (Site 4). Those streams with cooler temperatures likely had a greater proportion of groundwater flowing in them. Streamside vegetation that provides shading to the water can also prevent heat gain. The higher temperatures measured in the mainstem are likely due to the lack of riparian and overhanging vegetation, lack of tree canopy, lower proportion of groundwater inputs, and/or higher proportions of surface or point source inputs.

Dissolved oxygen concentrations in the Little Blue River and its tributaries varied from 7.8 mg/l in Rays Crossing (Site 2; storm flow) to 12.8 mg/l in Little Gilson Creek (Site 9; storm flow). DO in all streams exceeded the Indiana state minimum standard of 5 mg/l indicating the oxygen levels were sufficient to support aquatic life.

Because DO varies with temperature (cold water can contain more oxygen than warm water), it is relevant to examine DO saturation values. DO saturation refers to the amount of oxygen dissolved in water compared to the total amount possible when equilibrium between the stream water and the atmosphere is maximized. When a stream is less than 100% saturated with oxygen, decomposition processes within the stream may be consuming oxygen more quickly than it can be replaced and/or flow in the stream is not turbulent enough to entrain sufficient oxygen. The middle portion of the Little Blue River (Site 5) and two of the tributaries, Rays Crossing (Site 2) and Manilla Branch (Site 3), were 85-94% saturated with oxygen during base flow. This range is normal for streams during base flow. In contrast, all other sites exhibited supersaturated oxygen conditions during base flow; supersaturation ranged from 102% at Cotton Run (Site 4) to 148% at Little Gilson Creek (Site 9). All sites, except Manilla Branch (Site 3), Farmers Stream (Site 7), and Little Gilson Creek (Site 9), were 88-99% saturated during storm flow. In the three sites where supersaturated dissolved oxygen conditions occurred, supersaturation ranged from 101% at Manilla Branch (Site 3) and Farmers Stream (Site 7) to 121% at Little Gilson Creek (Site 9). Based on the amount of algal growth observed in the stream during sampling, it is likely supersaturated conditions present in Little Gilson Creek (Site 9) and the Headwaters (Site 10) are likely due to photosynthetic activity at these sites.

In general, both conductivity and pH values fell within acceptable ranges. Conductivity values in Little Blue River Watershed streams ranged from 470 µmhos at the Middle Little Blue River (Site 5) to 665 µmhos at Farmers Stream (Site 7) during base flow. All of the base flow measurements fell below the lower end of the range obtained by converting the IAC dissolved solids standard into specific conductance. pH values in the Little Blue River and its tributaries ranged from 7.8 at Rays Crossing (Site 2) to 8.3 at Farmers Stream (Site 7), the Upper Little Blue River (Site 8), and the Headwaters (Site 10). These pH values are within the range of 6-9 units established as acceptable by the Indiana Administrative Code for the protection of aquatic life.

Turbidity levels at two sites, Rays Crossing (Site 2; 29 NTUs) and the Upper Little Blue River (Site 8; 19 NTUs), exceeded the turbidity levels commonly found in Indiana streams (4.5-17.5 NTUs; White, unpublished). The high turbidity concentration at these two sites occurred during storm flow conditions. High turbidity was also noted in the reference stream during storm flow conditions. Samples collected from six sites, the three mainstem sites (Sites 1, 5, and 8), Rays Crossing (Site 2), the Headwaters (Site 10), and Conn's Creek (Reference Site), during storm flow sampling exceeded the USEPA recommended turbidity concentration (9.89 NTU; USEPA, 2000). The Lower Little Blue River (Site 1) possessed the highest turbidity (2.5 NTU) during base flow. Turbidity in all the streams was higher during storm flow. Typically during storm flow, turbidity is greater in streams due to increased overland flow carrying suspended sediments into the creek. This increase in turbidity following storm events suggests that stormwater throughout the Little Blue River Watershed carries larger amounts of dissolved and suspended solids than is present during base flow conditions.

Chemical and Bacterial Concentrations
Chemical and bacterial concentration data for the Little Blue River Watershed streams and the reference stream are listed by site in Table 56. Figures 55-62 present concentration information graphically.

Table 56. Chemical and bacterial characteristics of the Little Blue River Watershed stream samplings on June 13, July 30, and July 31, 2002. Shaded squares indicate those samples that were in violation of Indiana state standards (■) or recommended target values§ (□; Waters, 1995; Dodd et al., 1998; Ohio EPA, 1999; USEPA, 2000).

Site	Date	Timing	NO_3^--N (mg/l)	NH_3-N (mg/l)	TKN (mg/l)	SRP (mg/l)	TP (mg/l)	TSS (mg/l)	*E. coli* (#/100 ml)
1	7/30/03	Base	3.956	0.018*	0.382	0.047	0.061	6.04	310
	6/13/03	Storm	8.680	0.114	0.744	0.080	0.140	31.67	18,000
2	7/31/03	Base	3.937	0.029	0.339	0.045	0.066	3.33	170
	6/13/03	Storm	12.880	0.228	0.794	0.123	0.196	25.14	3,100
3	7/31/03	Base	5.823	0.018*	0.340	0.062	0.073	1.87	650
	6/13/03	Storm	12.246	0.067	0.230*	0.057	0.065	4.00	3,200
4	7/31/03	Base	4.084	0.018*	0.367	0.033	0.061	3.73	110
	6/13/03	Storm	12.199	0.041	0.271	0.035	0.040	4.25	760
5	10/31/03	Base	4.699	0.018*	0.230*	0.025	0.049	1.33	280
	6/13/03	Storm	6.409	0.047	0.463	0.053	0.103	25.25	2,000
6	7/31/03	Base	4.177	0.018*	0.383	0.046	0.037	1.20	190
	6/13/03	Storm	10.984	0.051	0.259	0.068	0.095	11.00	11,000
7	7/31/03	Base	8.697	0.018*	0.230*	0.019	0.017	1.28	330
	6/13/03	Storm	12.520	0.018*	0.230*	0.051	0.050	2.75	530
8	7/30/03	Base	3.963	0.018*	0.359	0.041	0.045	10.00	170
	6/13/03	Storm	8.875	0.087	0.458	0.062	0.136	31.71	3,500
9	7/30/03	Base	8.839	0.018*	0.230*	0.010*	0.028	4.20	66
	6/13/03	Storm	13.785	0.050	0.230*	0.040	0.057	5.00	360
10	7/30/03	Base	2.678	0.018*	0.615	0.044	0.010*	6.00	140
	6/13/03	Storm	8.013	0.130	0.435	0.056	0.120	34.67	780
Ref	7/30/03	Base	5.202	0.018*	0.616	0.047	0.076	5.73	650
	6/13/03	Storm	12.128	0.096	0.519	0.121	0.203	47.67	22,000

§Most recommended criteria were developed based on base flow data; therefore, these criteria are not directly comparable to data collected during storm flow events.
* Method Detection Limit

Nitrate-nitrogen concentrations during base and storm flow conditions were elevated at all sites (Figure 55). Nitrate-nitrogen concentrations measured during storm flow sampling were greater than concentrations measured in base flow samples at all sites. Base flow concentrations ranged from 2.68 mg/l at the Headwaters (Site 10) to 8.84 mg/l at Little Gilson Creek (Site 9), while storm flow nitrate-nitrogen concentrations ranged from 6.41 mg/l at the Middle Little Blue River (Site 8) to 13.78 mg/l at Little Gilson Creek (Site 9). Little Gilson Creek exhibited the highest nitrate-nitrogen concentration during both base and storm flow sampling. Nitrate-nitrogen concentrations observed along the mainstem of the Little Blue River during both base and storm flow were higher than the median nitrate-nitrogen concentration observed in Ohio streams (1.0 mg/l) known to support healthy warmwater fauna (Ohio EPA, 1999). Likewise, all of the tributaries possessed nitrate-nitrogen concentrations greater than the median concentration observed in Ohio streams (1.6 mg/l) known to support modified warmwater fauna (Ohio EPA, 1999). Additionally, all sites exceeded the USEPA recommended criterion for nitrate-nitrogen of 0.63 mg/l for streams in the Central Corn Belt Plains Ecoregion, which includes the Little Blue River Watershed (USEPA, 2000). Furthermore, concentrations at all tributaries and the reference site during storm flow were greater than 10 mg/l, the concentration set by the Indiana Administrative Code for safe drinking water.

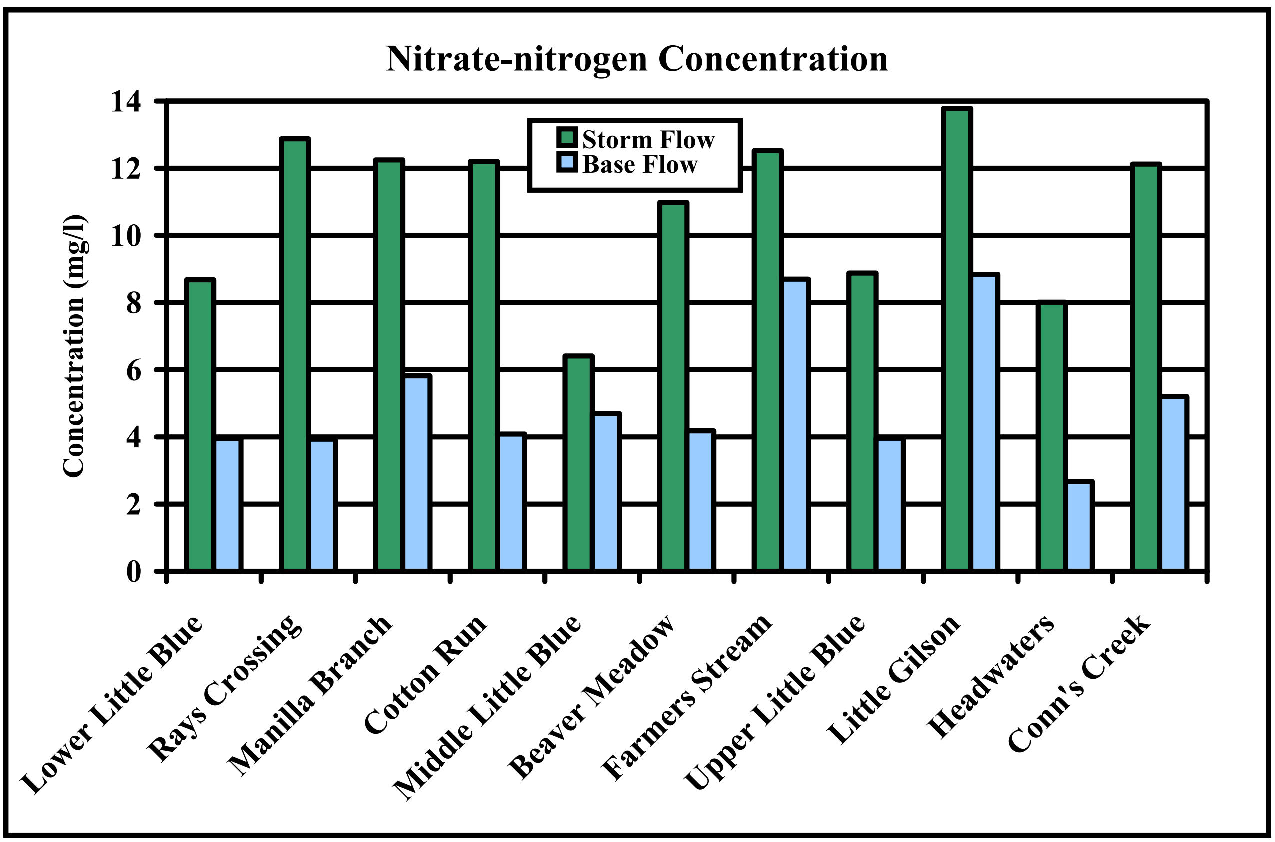


Figure 55. Nitrate-nitrogen concentration measurements during base flow and storm flow sampling of Little Blue River Watershed streams. Detection limit is 0.022 mg/l.

In contrast to the nitrate-nitrogen concentrations, ammonia-nitrogen concentrations were relatively low at all sites during base and storm flow sampling (Figure 56). Under base flow conditions, Rays Crossing (Site 2) exhibited the highest ammonia-nitrogen concentration (0.029 mg/l), while all other sites contained concentrations below the laboratory detection level (0.018 mg/l). The elevated ammonia-nitrogen concentrations coupled with lowered levels of dissolved oxygen in Rays Crossing (Site 2) suggest that decomposition may be occurring at this site. Ammonia-nitrogen concentrations during storm flow conditions ranged from below the detection level (0.018 mg/l) at Farmers Stream (Site 7) to 0.228 mg/l at Rays Crossing (Site 2). Elevated ammonia-nitrogen concentrations in Rays Crossing (Site 2) and the Lower Little Blue River (Site 1) may be affecting the aquatic life within these streams. None of the samples collected during base or storm flow exceeded the IAC ammonia-nitrogen standard for the protection of aquatic life.

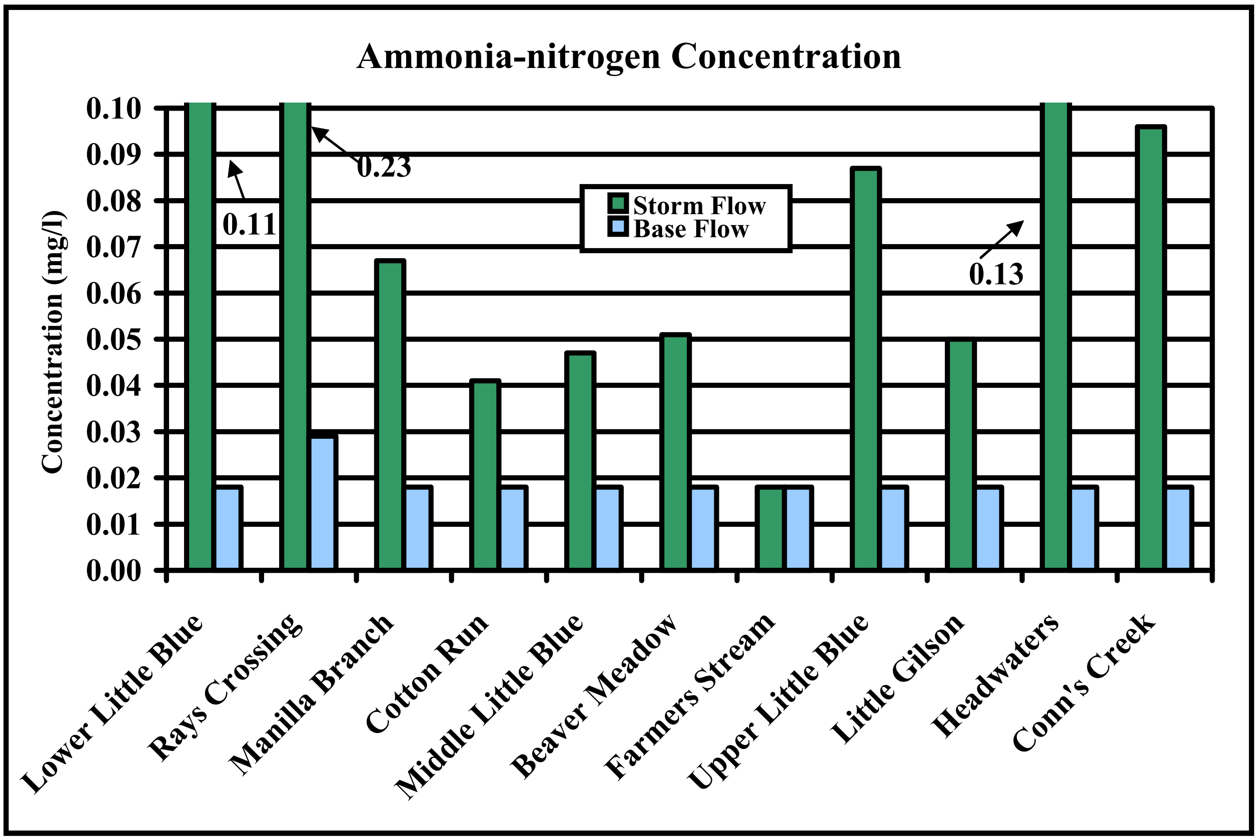


Figure 56. Ammonia-nitrogen concentration measurements during base flow and storm flow sampling of Little Blue River Watershed streams. Detection limit is 0.018 mg/l.

Total Kjeldahl nitrogen concentrations in the study streams were low for Indiana streams (Figure 57). Base flow concentrations ranged from below the laboratory detection level (0.230 mg/l) at Middle Little Blue River (Site 8), Farmers Stream (Site 7), and Little Gilson Creek (Site 9) to 0.615 mg/l at the Headwaters (Site 10) and the reference site (Conn's Creek), while storm flow nitrate-nitrogen concentrations ranged from below the laboratory detection level (0.230 mg/l) at Manilla Branch (Site 3), Farmers Stream (Site 7), and Little Gilson Creek (Site 9) to 0.794 mg/l at Rays Crossing (Site 2). High TKN concentration at Rays Crossing (Site 2) and the Lower Little Blue River (Site 1) suggest the presence of organic matter at these sites. TKN levels exceeded USEPA recommended concentration (0.591 mg/l) at the Lower Little Blue River (Site 1) and Rays Crossing (Site 2) during storm flow and at the Headwaters (Site 10) and Conn's Creek (Reference Site) during base flow; however, these TKN concentrations are typical or even low for Indiana streams.

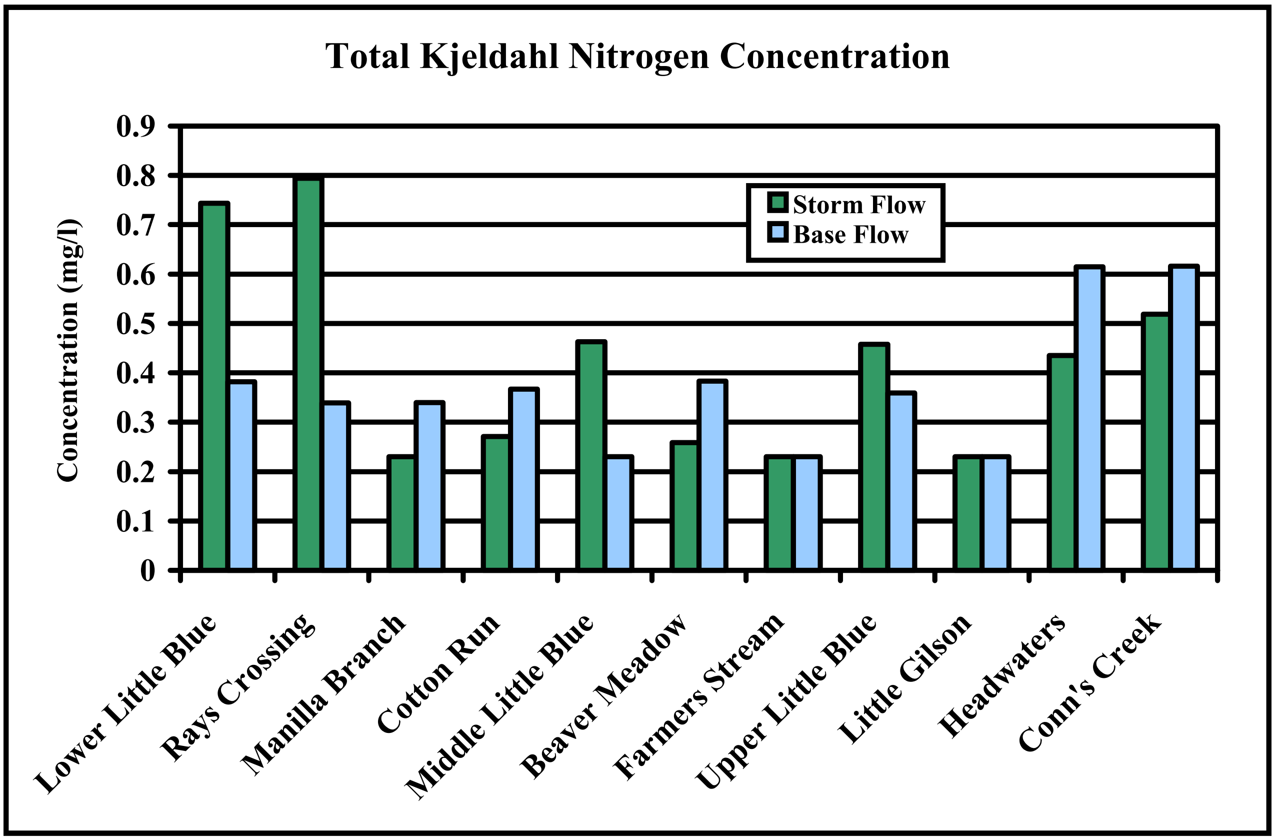


Figure 57. Total Kjeldahl nitrogen (TKN) concentration measurements during base flow and storm flow sampling of Little Blue River Watershed streams. Detection limit is 0.230 mg/l.

Storm flow soluble reactive phosphorus concentrations exceeded concentrations measured during base flow at all sites except the Manilla Branch (Site 3; Figure 58). During storm flow conditions, Rays Crossing (Site 2) exhibited the highest soluble reactive phosphorus concentration (0.123 mg/l), while Cotton Run (Site 4) possessed the lowest SRP concentration (0.035 mg/l). Little Gilson Creek (Site 9) contained the lowest soluble reactive phosphorus concentration (below detection level; <0.010 mg/l) during base flow. The Manilla Branch (Site 3) possessed the highest SRP concentration (0.062 mg/l) during base flow.

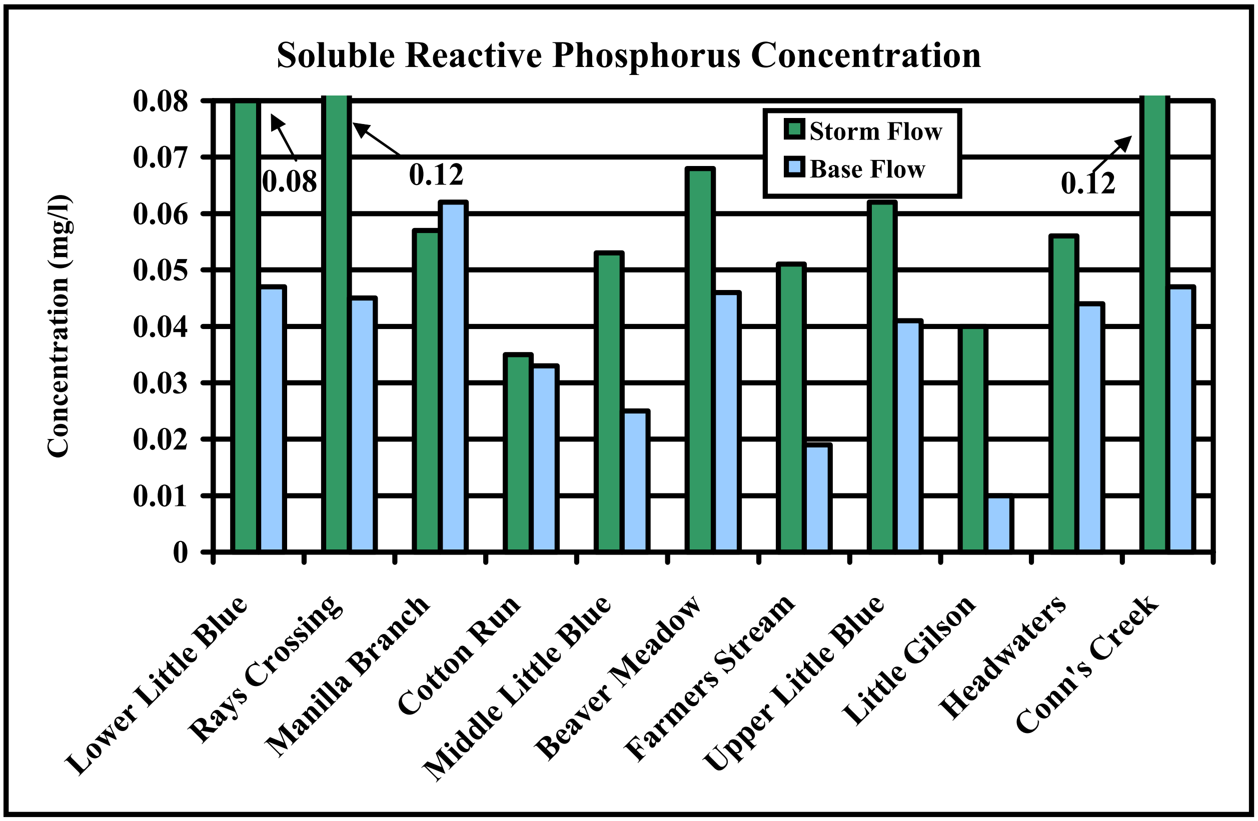


Figure 58. Soluble reactive phosphorus (SRP) concentration measurements during base flow and storm flow sampling of Little Blue River Watershed streams. Detection limit is 0.010 mg/l.

Samples from most streams revealed that the soluble phosphorus fraction was greater than half of the total phosphorus concentration suggesting that most phosphorus loading was dissolved, available phosphorus, not particulate soil-associated phosphorus (Figure 59). Beaver Meadow Creek (Site 6) during base flow and Farmers Stream (Site 7) during base and storm flow possessed soluble reactive phosphorus concentrations that exceeded the respective total phosphorus concentrations. This is a result of limitations involved with laboratory sample analysis and field sampling procedure. The results reported in Table 56 fell within accepted ranges established in the project's Quality Assurance/Quality Control plan. The results suggest that nearly all of the total phosphorous in these samples consisted of dissolved phosphorus. Little Gilson Creek (Site 9) during base flow and the Upper Little Blue River (Site 8) and the Headwaters (Site 10) during storm flow exhibited soluble phosphorus fractions less than half of the total phosphorus concentration suggesting that most phosphorus loading was particulate or soil-associated. All sites except Manilla Branch (Site 3), Cotton Run (Site 4), Farmers Stream (Site 7), and Little Gilson Creek (Site 9) exhibited higher particulate phosphorus levels during storm events than those present during base flow. Elevated particulate phosphorus levels in streams following storm events are indicative of soil loss via erosion since particulate phosphorus is typically adsorbed to soil particles.

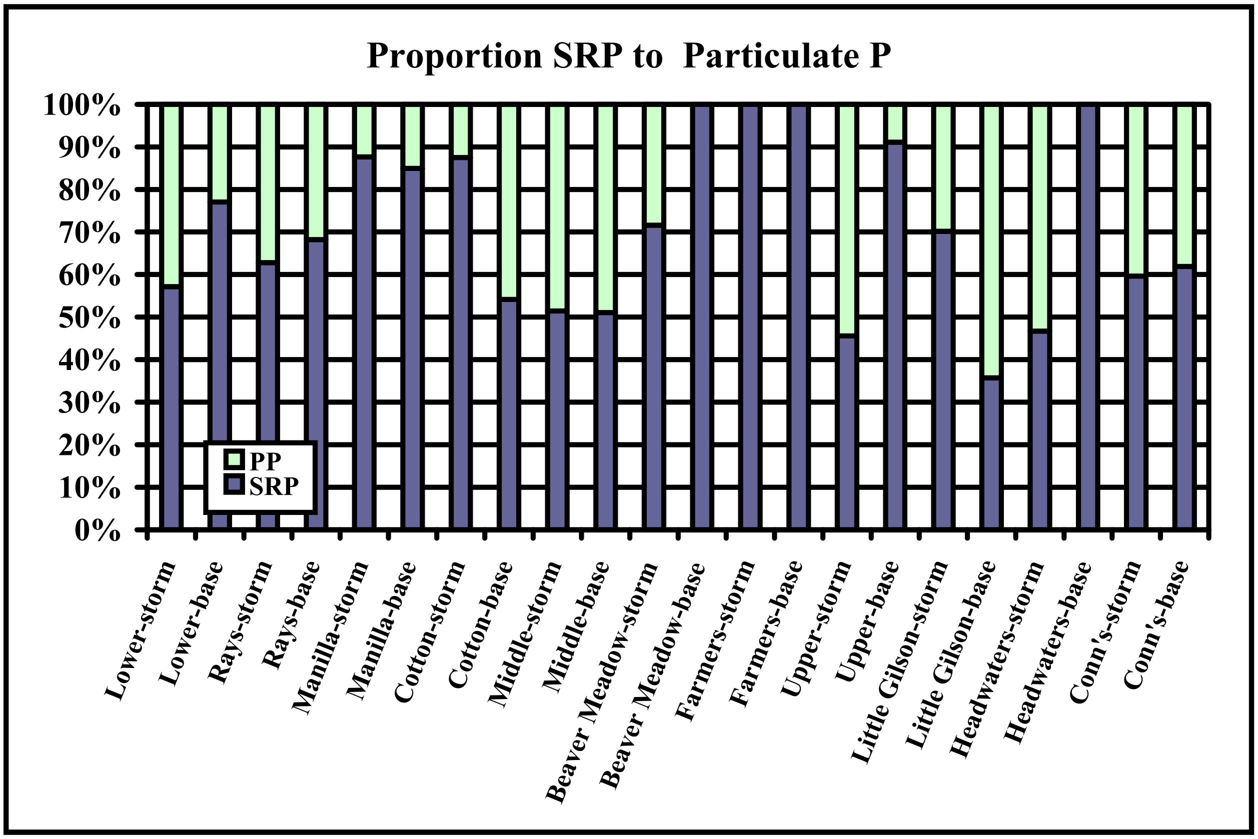


Figure 59. Soluble reactive phosphorus percentage of total phosphorus concentration measurements during base flow and storm flow sampling of Little Blue River Watershed streams. TP concentration minus SRP concentration yields an estimation of particulate phosphorus.

Generally, total phosphorus concentrations measured during storm flow sampling exceeded those measured during base flow (Figure 60). During base flow conditions, the Headwaters (Site 10) possessed the lowest total phosphorus concentration (below detection limit; <0.010 mg/l), while the Manilla Branch (Site 3) contained the highest concentration (0.073 mg/l). Cotton Run (Site 4) possessed the lowest total phosphorus concentration (0.040 mg/l) during storm flow with Rays Crossing (Site 2; 0.196 mg/l) and the reference site (Conn's Creek; 0.203 m/l) containing the highest total phosphorus concentrations. The Little Blue River mainstem sites (Sites 1, 5, and 8), Rays Crossing (Site 2), Beaver Meadow Creek (Site 6), and the Headwaters (Site 10) during storm flow and the reference site during both base and storm flow possessed total phosphorus concentrations that meet or exceed the USEPA recommended criterion (0.076 mg/l) for the ecoregion (USEPA, 2000). These same sites possessed concentrations above the level found by Dodd et al. (0.076 mg/l; 1998) to mark the boundary between mesotrophic and eutrophic concentrations, suggesting that these systems are eutrophic. Likewise, all of the Little Blue River mainstem sites (Sites 1, 5, and 8) during storm flow possessed total phosphorus concentrations greater than the median level (0.10 mg/l) measured in streams classified as warmwater habitat (Ohio EPA, 1999). However, none of the tributaries possessed total phosphorus concentrations greater than the median level (0.28 mg/l) measured in streams classified as modified warmwater habitat (Ohio EPA, 1999). The Ohio EPA uses these levels (WWH, 0.10 mg/l; MWH, 0.28 mg/l) as the maximum total phosphorus concentrations to avoid impairment of aquatic life in warmwater and modified warmwater habitat streams, respectively. The elevated total phosphorus concentrations and resultant productivity along the Little Blue River mainstem and in Rays Crossing, Beaver Meadow Creek, and the Headwaters may be altering the biotic community structure and impairing aquatic life in these streams.

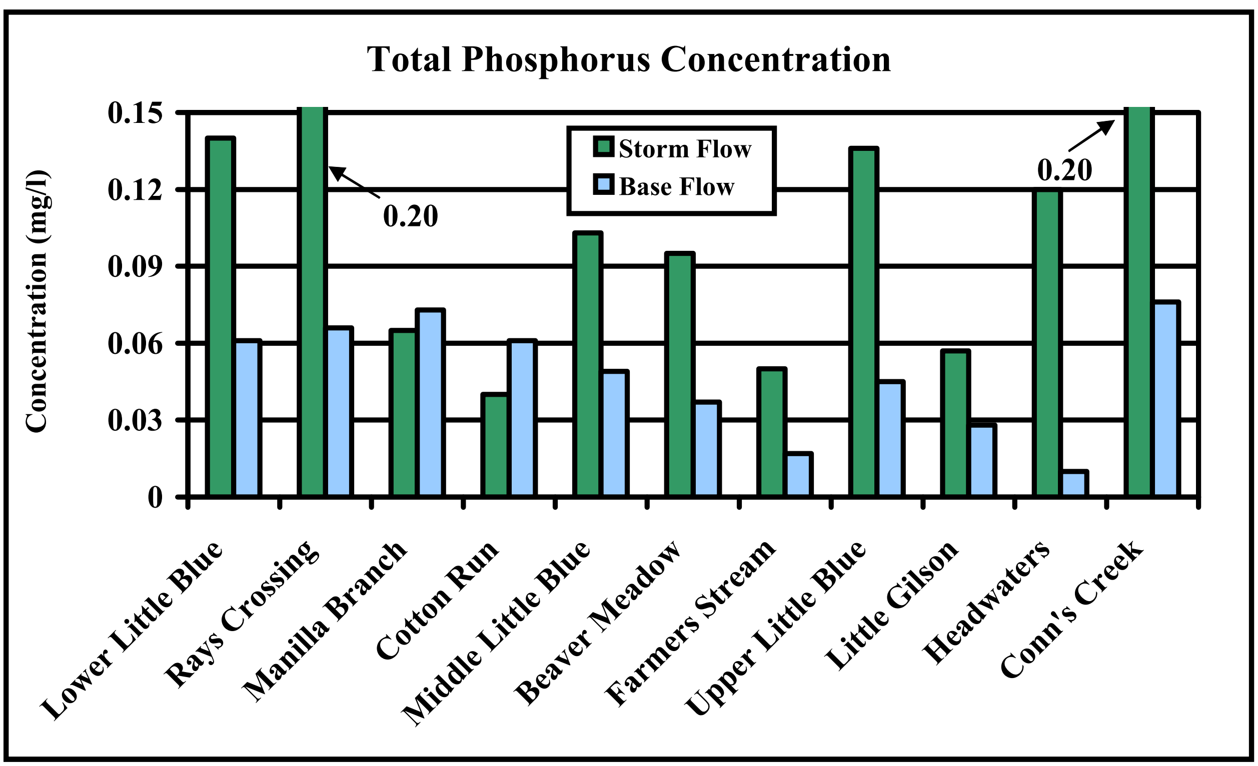


Figure 60. Total phosphorus (TP) concentration measurements during base flow and storm flow sampling of Little Blue River Watershed streams. Detection limit is 0.010 mg/l.

Total suspended solids concentration measured during storm flow exceeded concentrations measured during base flow samples at all sample sites (Figure 61). Higher overland flow velocities typically result in an increase in sediment particles in runoff. Additionally, greater streambank and streambed erosion typically occurs during high flow. Therefore, higher concentrations of suspended solids are typically measured in storm flow samples. During both base and storm flow, the Little Blue River mainstem sites possessed higher total suspended solids concentrations than those measured in all of the tributary sites except in the Headwaters (Site 10) during storm flow. The storm flow samples collected at the Headwaters (Site 10), Lower Little Blue River (Site 1), and the Upper Little Blue River (Site 8) exhibited the highest total suspended solids concentrations (35 mg/l, 31.7 mg/l, and 31.7 mg/l, respectively) of the watershed streams. Conn's Creek (Reference Site) possessed a higher total suspended solids concentration than any of these sites during storm flow (48 mg/l). None of the samples possessed total suspended solids concentrations that exceed the concentration found to be deleterious to aquatic life (Waters, 1995).

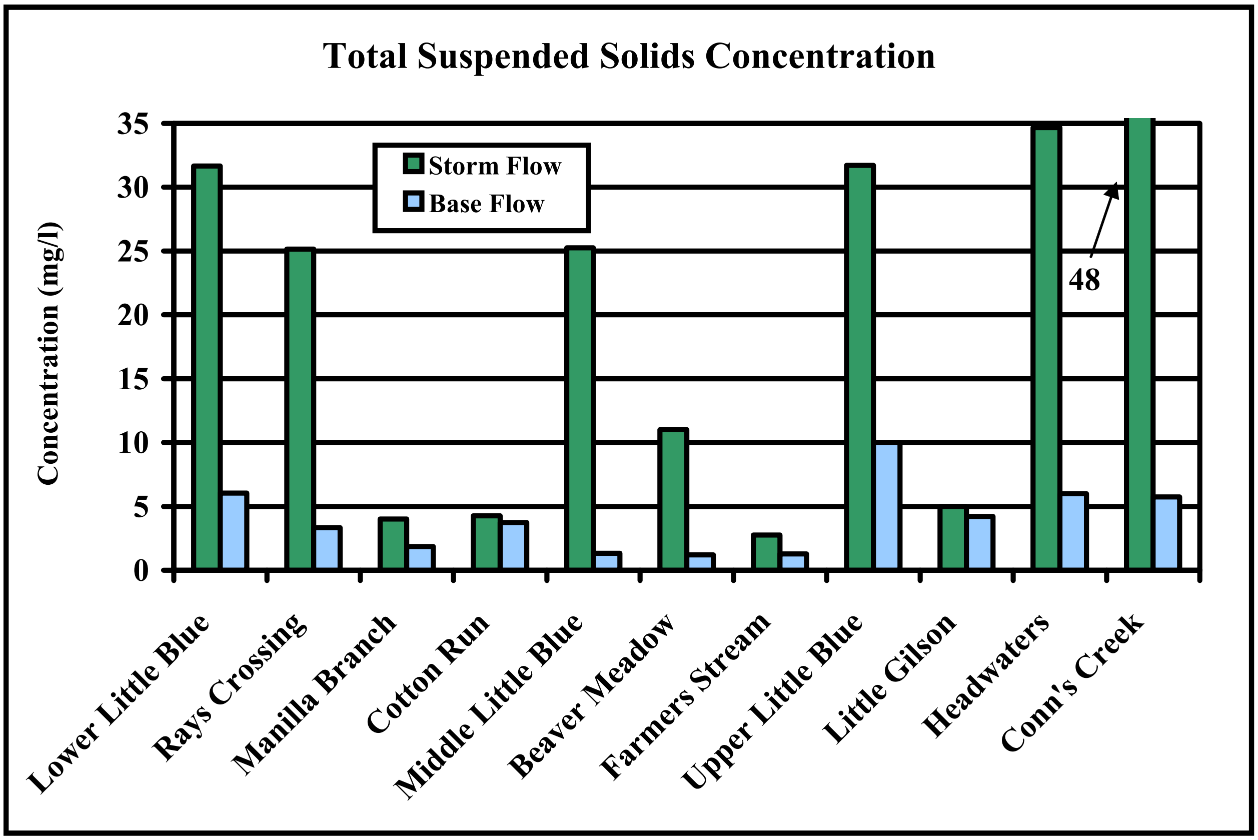


Figure 61. Total suspended solid (TSS) concentration measurements during base flow and storm flow sampling of Little Blue River Watershed streams.

Figure 62 displays the *E. coli* concentration data for the Little Blue River and its tributaries. *E. coli* concentrations exceeded the Indiana state standard (235 colonies/100 ml) for state waters at the Lower Little Blue River (Site 1), Manilla Branch (Site 3), Middle Little Blue River (Site 5), Farmers Stream (Site 7), and Conn's Creek (Reference Site) during base flow. During storm flow, all *E. coli* concentrations measured in the Little Blue River streams and Conn's Creek exceeded the Indiana state standard. Storm flow concentrations measured at the Lower Little Blue River (Site 1) were approximately 75 times the state standard. Likewise, *E. coli* concentrations measured in Beaver Meadow Creek (Site 6) were approximately 45 times the state standard. High *E. coli* concentrations suggest the presence of other pathogens. These pathogens may impair the biota in the Little Blue River and its tributaries and limit human use of the streams. The sources of *E. coli* in the Little Blue River and its tributaries have not been identified; however, wildlife, livestock, and/or domestic animal defecation; manure fertilizers; previously contaminated sediments; and failing or improperly sited septic systems are common sources of the bacteria.

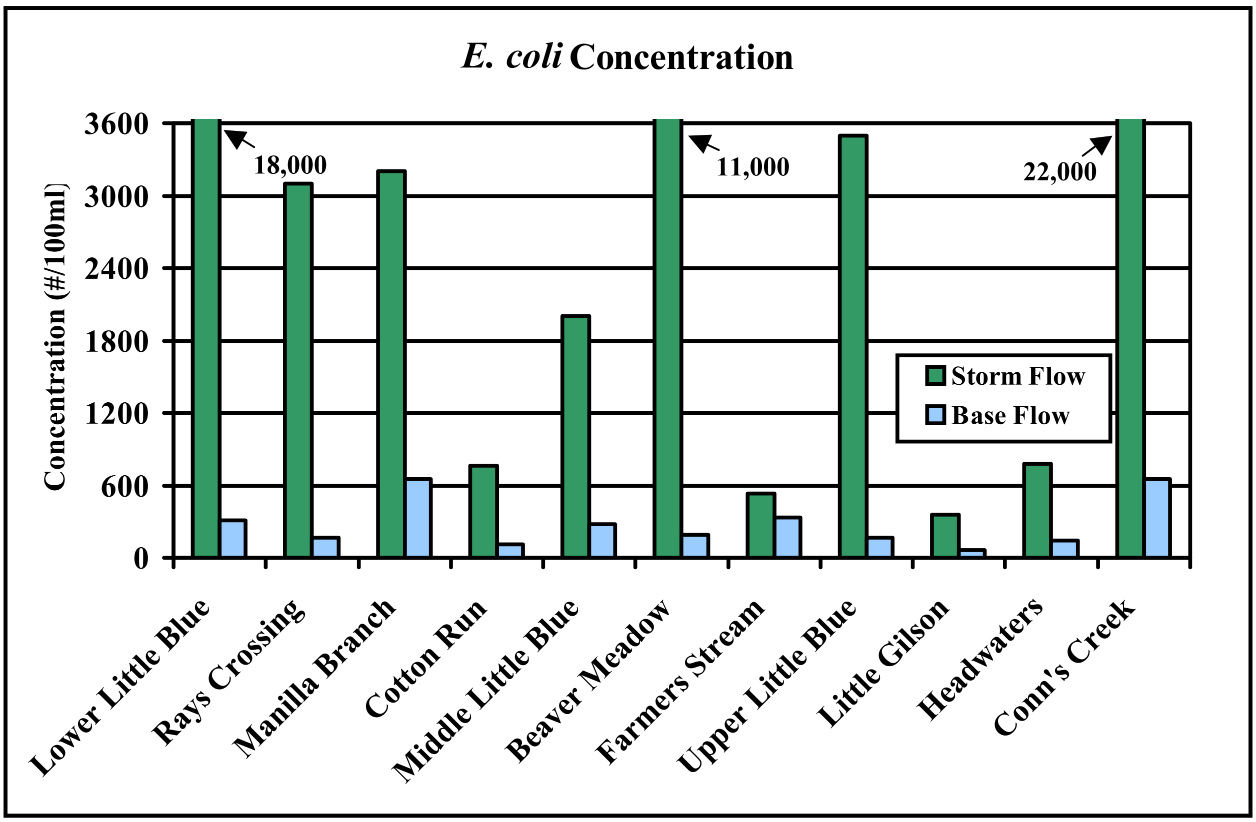


Figure 62. *E. coli* bacteria concentration measurements during the storm flow sampling of Little Blue River Watershed streams.

Sediment and Chemical Loading

Table 57 lists the chemical and sediment mass loading data for Little Blue River Watershed by site. Figures 63-68 present mass loading information graphically.

Table 57. Chemical loading data for watershed streams.

Site	Date	Timing	NO_3^--N Load (kg/d)	NH_3-N Load (kg/d)	TKN Load (kg/d)	SRP Load (kg/d)	TP Load (kg/d)	TSS Load (kg/d)
1	7/30/03	Base	304.6	1.4	29.4	3.6	4.7	465.4
	6/13/03	Storm	2,597.8	34.1	222.7	23.9	41.9	9,477.4
2	7/31/03	Base	1.5	0.0	0.1	0.0	0.0	1.3
	6/13/03	Storm	415.7	7.4	25.6	4.0	6.3	811.5
3	7/31/03	Base	12.0	0.0	0.7	0.1	0.1	3.8
	6/13/03	Storm	149.7	0.8	2.8	0.7	0.8	48.9
4	7/31/03	Base	0.3	0.0	0.0	0.0	0.0	0.3
	6/13/03	Storm	107.4	0.4	2.4	0.3	0.4	37.4
5	10/31/03	Base	247.6	0.9	12.1	1.3	2.6	70.2
	6/13/03	Storm	982.6	7.2	71.0	8.1	15.8	3,871.1
6	7/31/03	Base	45.2	0.2	4.1	0.5	0.4	13.0
	6/13/03	Storm	311.5	1.4	7.3	1.9	2.7	312.0
7	7/31/03	Base	134.2	0.3	3.5	0.3	0.3	19.7
	6/13/03	Storm	49.0	0.1	0.9	0.2	0.2	10.8
8	7/30/03	Base	130.9	0.6	11.9	1.4	1.5	330.3
	6/13/03	Storm	902.7	8.8	46.6	6.3	13.8	3,225.9
9	7/30/03	Base	70.2	0.1	1.8	0.1	0.2	33.4
	6/13/03	Storm	80.9	0.3	1.3	0.2	0.3	29.3
10	7/30/03	Base	33.9	0.2	7.8	0.6	0.1	76.0
	6/13/03	Storm	309.6	5.0	16.8	2.2	4.6	1,339.3
Ref	7/30/03	Base	160.8	0.6	19.0	1.5	2.3	177.2
	6/13/03	Storm	2,301.2	18.2	98.5	23.0	38.5	9,044.4

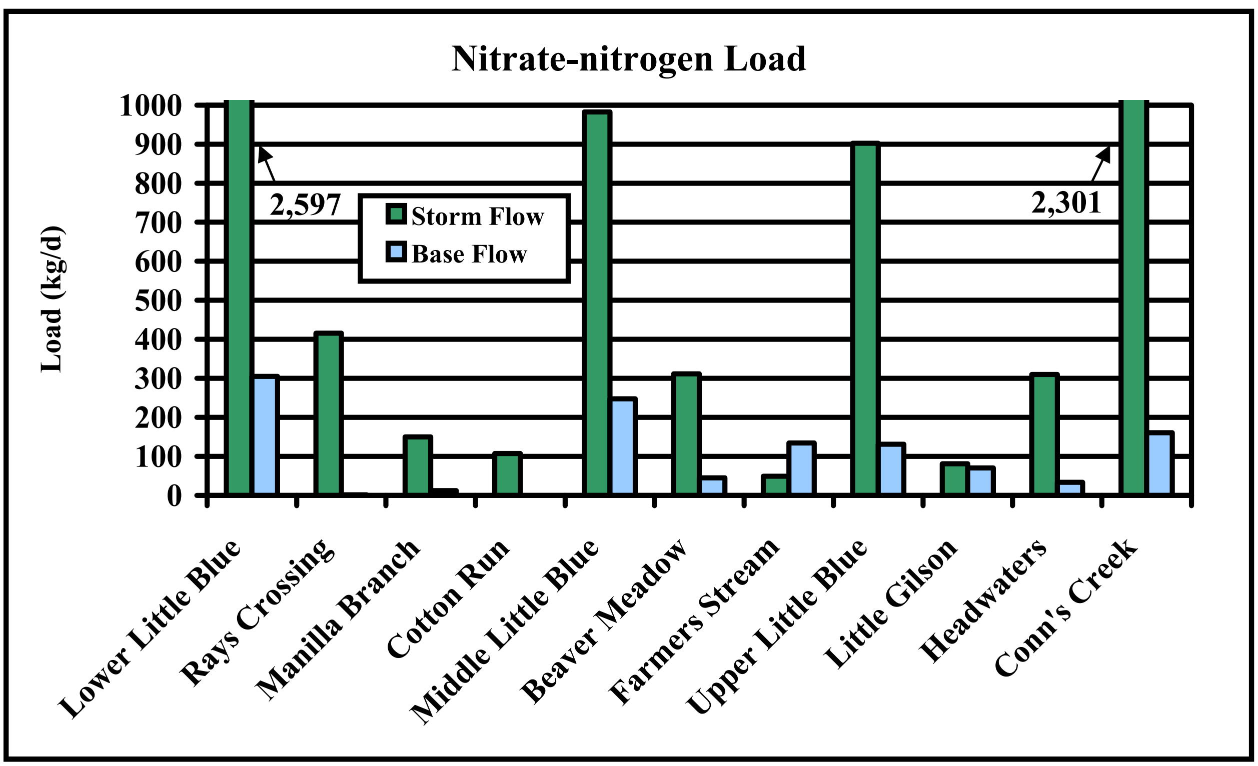


Figure 63. Nitrate-nitrogen loading rates during base flow and storm flow sampling of Little Blue River Watershed streams.

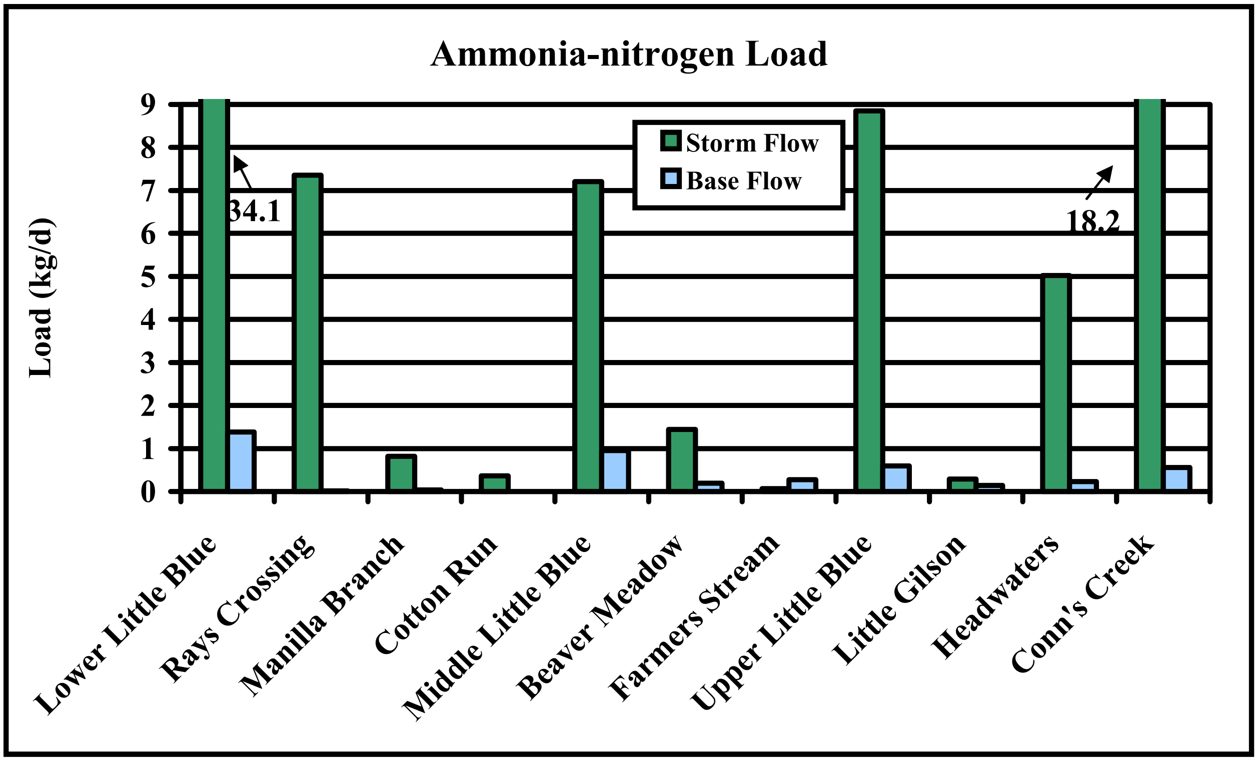


Figure 64. Ammonia-nitrogen loading rates during base flow and storm flow sampling of Little Blue River Watershed streams.

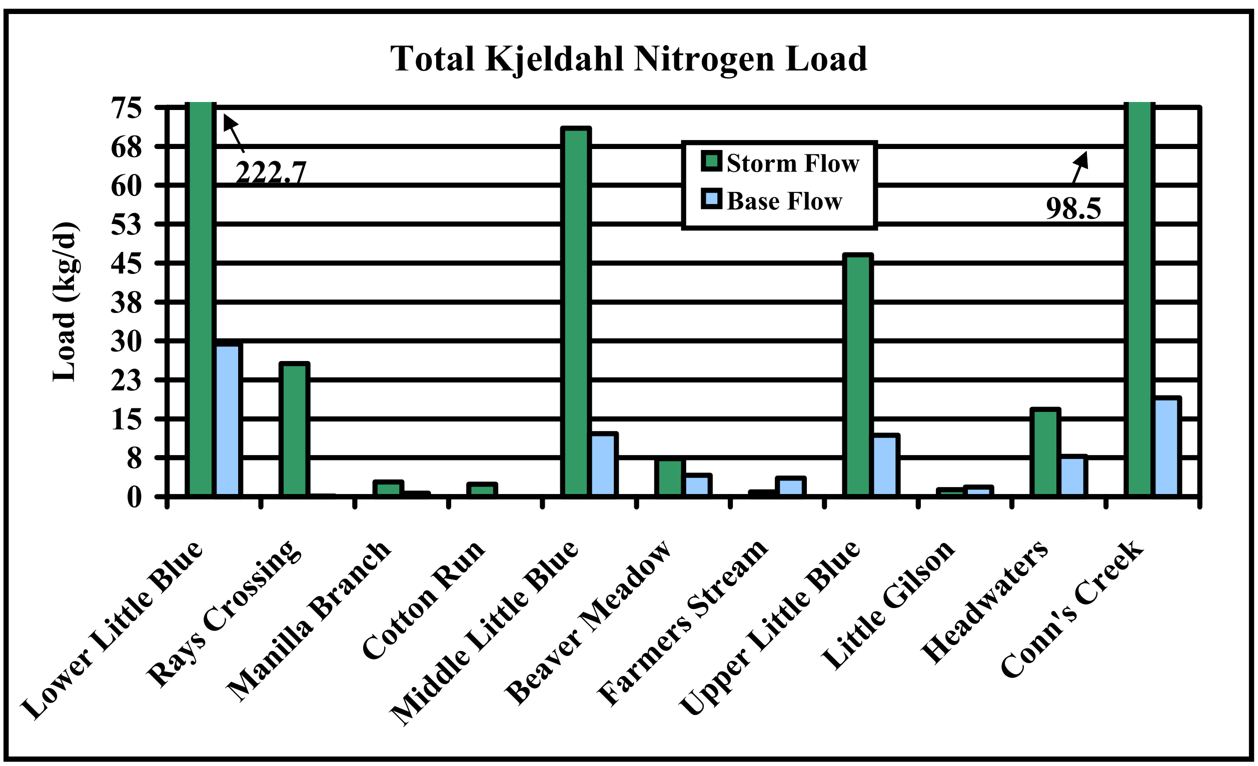


Figure 65. Total Kjeldahl nitrogen loading rates during base flow and storm flow sampling of Little Blue River Watershed streams.

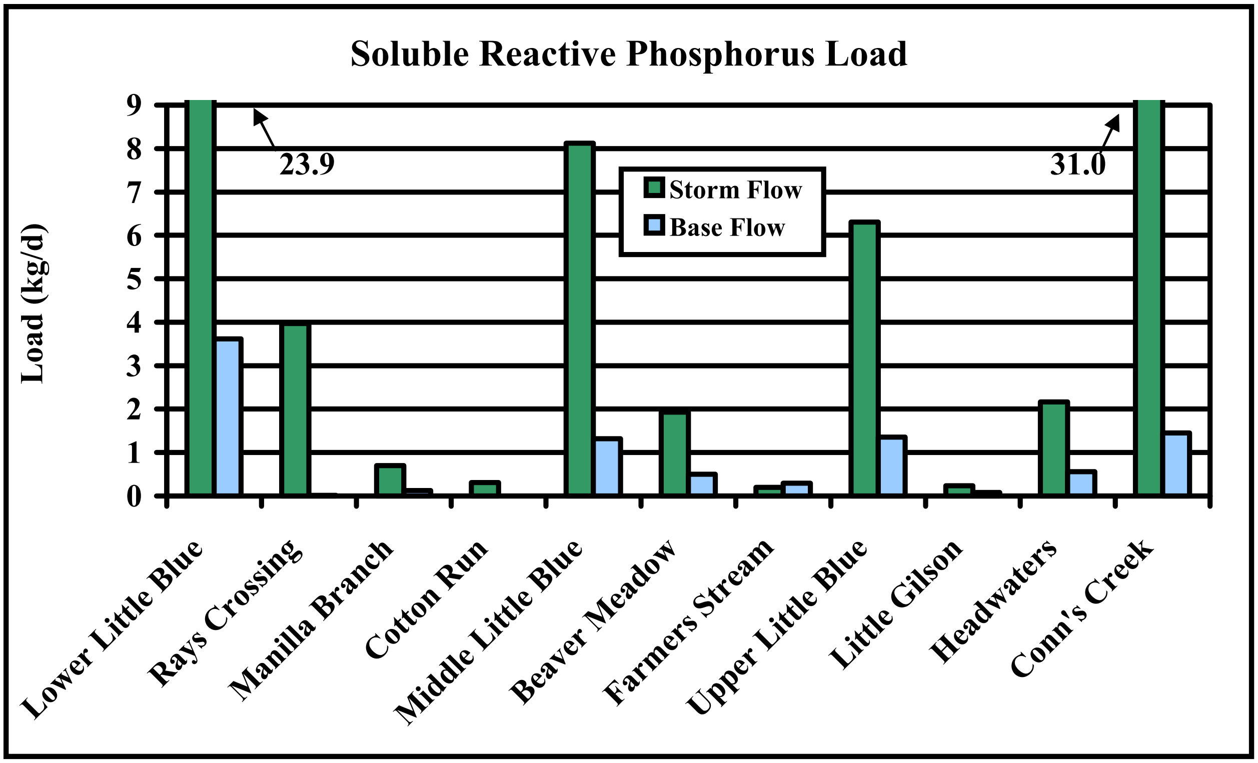


Figure 66. Soluble reactive phosphorus loading rates during base flow and storm flow sampling of Little Blue River Watershed streams.

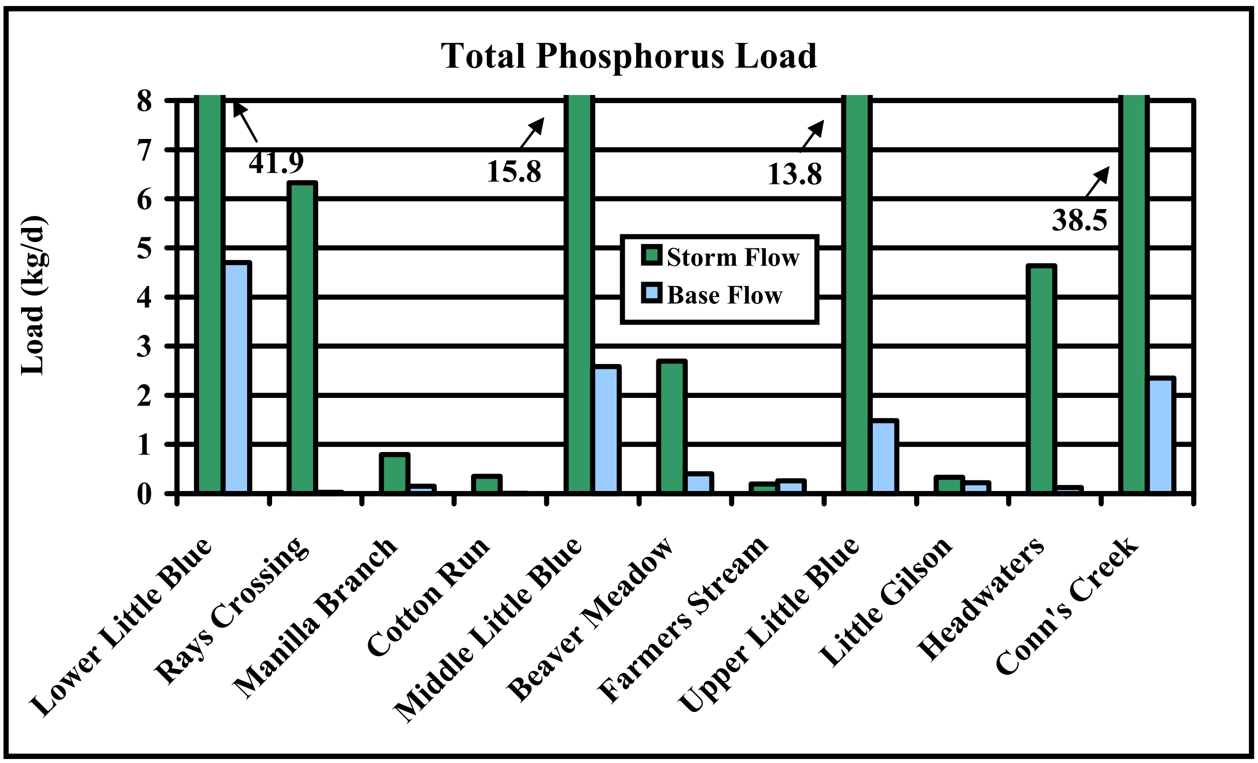


Figure 67. Total phosphorus loading rates during base flow and storm flow sampling of Little Blue River Watershed streams.

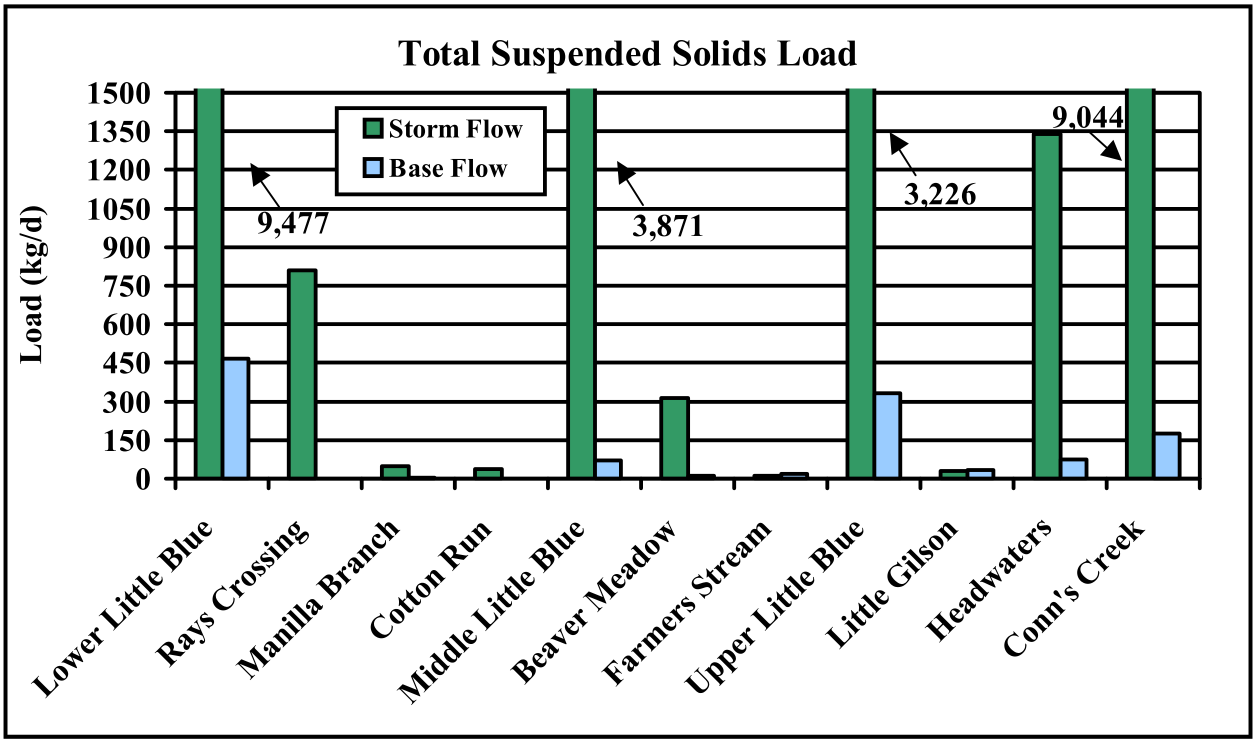


Figure 68. Total suspended solids loading rates during base flow and storm flow sampling of Little Blue River Watershed streams.

Under storm flow conditions, the Lower Little Blue River (Site 1) possessed the greatest loads for all parameters. Pollutant loads in Conn's Creek were similar to those observed in the Lower Little Blue River (Site 1). The Lower Little Blue River (Site 1) possessed the greatest loads of nitrate-nitrogen, ammonia-nitrogen, total Kjeldahl nitrogen, soluble reactive phosphorus, total phosphorus, and total suspended solids concentrations during base flow. This is to be expected; since the site is located furthest downstream, it receives pollutants from all other sites.

Some stream systems can process or assimilate pollutants rather than transporting them downstream. The drop in ammonia-nitrogen concentration between the Upper Little Blue River (Site 8) and the Middle Little Blue River (Site 5) may be due to the conversion of ammonia to nitrate. Ammonia readily oxidizes to nitrate in the presence of oxygen. The riffle habitat present at the Middle Little Blue River (Site 5) provides an excellent opportunity for oxygen to diffuse into the water column.

Of the six major tributaries to the Little Blue River, Rays Crossing (Site 2) during storm flow and Beaver Meadow Creek (Site 6), Farmers Stream (Site 7), and Little Gilson Creek (Site 9) during base flow delivered the greatest pollutant loads to the Little Blue River mainstem. Under storm flow conditions, Rays Crossing (Site 2) delivered more nitrate-nitrogen, ammonia-nitrogen, total Kjeldahl nitrogen, soluble reactive phosphorus, total phosphorus, and total suspended solids than the other tributaries to the Little Blue River. Farmers Stream (Site 7) carried more nitrate-nitrogen and ammonia-nitrogen to the Little Blue River under base flow conditions. During base flow, Beaver Meadow Creek (Site 6) delivered more total Kjeldahl nitrogen, soluble reactive phosphorus, and total phosphorus to the Little Blue River mainstem. Little Gilson Creek (Site 9) carried the higher load of total suspended solids to the Little Blue River mainstem during base flow.

Areal Loading

In an effort to normalize the nutrient and sediment loading rates, the rates were divided by subwatershed size above each sampling site. This means that mainstem subwatershed acreages combine the entire portion of the Little Blue River Watershed that drains through the respective sampling site. For instance, the Middle Little Blue River receives water from both the Upper Little Blue River and the Middle Little Blue River Subwatersheds; therefore, the acreage used to calculate areal loading was the combination of both of these subwatersheds.

Generally, sediment and nutrient areal loading was lower during low flow conditions than during storm flow conditions for all subwatersheds (Table 58). The Rays Crossing Tributary Subwatershed contributed more ammonia-nitrogen, total Kjeldahl nitrogen, total phosphorus, and total suspended solids during storm flow than any other subwatershed. The Rays Crossing Tributary Subwatershed also contributed the highest ammonia-nitrogen and soluble reactive phosphorus and the second highest total Kjeldahl nitrogen, total phosphorus, and total suspended solids during base flow conditions. During base flow, Cotton Run contained the highest per unit area loads of total Kjeldahl nitrogen, total phosphorus, and total suspended solids. This indicates that on a regular basis the Rays Crossing Tributary and Cotton Run Subwatersheds deliver more sediment and sediment-attached pollutants per unit area to the Little Blue River than most of the other subwatersheds. Farmers Stream loaded more nitrate-nitrogen per unit area during both base and storm flow conditions than any of the other subwatersheds. With the exception of soluble reactive phosphorus, the mainstem Little Blue River and Beaver Meadow Creek Subwatershed typically contributed the lowest load per area of all of the parameters sampled.

Table 58. Areal loading of sediment and nutrients by subwatershed based on base and storm flow sampling events.

Subwatershed	Watershed Size	Timing	NO_3^--N Load (kg/ha-yr)	NH_3-N Load (kg/ha-yr)	TKN Load (kg/ha-yr)	SRP Load (kg/ha-yr)	TP Load (kg/ha-yr)	TSS Load (kg/ha-yr)
Lower Little Blue River	67,481 ac (27,320 ha)	Base	15.82	0.07	1.53	0.32	0.24	24.17
		Storm	34.71	0.46	2.97	0.05	0.56	126.62
Rays Crossing	2,500 ac (1,012 ha)	Base	424.85	3.13	36.58	1.43	7.12	359.67
		Storm	1,389.90	24.60	85.68	0.01	21.15	2,713.22
Manilla Branch	2,923 ac (1,183 ha)	Base	537.43	1.66	31.38	0.21	6.74	172.31
		Storm	1,130.23	6.18	21.23	0.04	6.00	369.17
Cotton Run	2,206 ac (893 ha)	Base	499.46	2.20	44.88	0.13	7.46	456.54
		Storm	1,491.91	5.01	33.14	0.00	4.89	519.77
Middle Little Blue River	44,012 ac (17,818 ha)	Base	28.81	0.11	1.41	0.17	0.30	8.17
		Storm	39.29	0.29	2.84	0.03	0.63	154.80
Beaver Meadow Creek	12,584 ac (5,093 ha)	Base	89.56	0.39	8.21	0.14	0.79	25.73
		Storm	235.51	1.09	5.55	0.04	2.04	235.85
Farmers Stream	2,006 ac (812 ha)	Base	1,169.97	2.42	30.94	0.09	2.29	171.79
		Storm	1,684.27	2.42	30.94	0.13	6.73	369.95
Upper Little Blue River	23,478 ac (9,501 ha)	Base	45.55	0.21	4.13	0.24	0.52	114.93
		Storm	102.00	1.00	5.26	0.05	1.56	364.48
Little Gilson Creek	3,164 ac (1,280 ha)	Base	753.83	1.54	19.62	0.07	2.39	358.19
		Storm	1,175.64	4.26	19.62	0.02	4.86	426.42
Headwaters	10,891 ac (4,407 ha)	Base	66.35	0.45	15.24	0.18	0.25	148.66
		Storm	198.53	3.22	10.78	0.05	2.97	858.91

6.2.3 Water Chemistry Summary

In general, physical and chemical parameter data collected from streams in the Little Blue River Watershed indicate evidence of water quality degradation when compared with ideal conditions. Nitrate-nitrogen and *E. coli* concentrations were elevated throughout the watershed. Tributary nitrate-nitrogen concentrations exceeded the median nitrate-nitrogen level (1.6 mg/l) observed in modified Ohio streams that support aquatic life during both base and storm flow, while mainstem nitrate-nitrogen concentrations exceeded the median level (1.0 mg/l) observed in unmodified warmwater streams during both base and storm flow. All tributaries and the reference site exceeded the Indiana state standard for nitrate-nitrogen (10 mg/l) during storm flow. Similarly, bacteria concentrations were high during both base and storm flow conditions. Four sites possessed *E. coli* concentrations that exceeded the Indiana state standard during base flow, while all samples exceeded the standard during storm flow. At sites where elevated concentrations were observed, concentrations were 1.2 to 76 times the state standard. Additionally, bacteria levels were high when compared with other agricultural watersheds in Indiana. The Lower Little Blue River contributed higher loads for all parameters during both base and storm flow sampling. During storm flow, the Rays Crossing Tributary delivered more sediment and sediment-attached pollutants to the Little Blue River than any of the other tributaries. Under base flow conditions, Farmers Stream carried more nitrate-nitrogen and ammonia-nitrogen, the Headwaters contained more total Kjeldahl nitrogen, Beaver Meadow Creek delivered more soluble reactive and total phosphorus, and Little Gilson Creek contained higher total suspended solids loads than the other tributaries. Sediment loading rates varied but were high at some sites ranging from 0.3 to 9,477 kg/day (0.7 to 20,893 lbs/day) depending on flow conditions and location.

While some subwatersheds per unit area delivered low nutrient and sediment loads others delivered significant loads of the parameters particularly during the storm event. Rays Crossing Tributary contributed more ammonia-nitrogen, total Kjeldahl nitrogen, total phosphorus, and total suspended solids during storm flow than any of the other subwatersheds. During base flow, Cotton Run contained the highest per unit area loads of total Kjeldahl nitrogen, total phosphorus, and total suspended solids. Farmers Stream delivered the highest nitrate-nitrogen load per unit area during both base and storm flow conditions. According to the stream chemistry data, some streams can be classified as relatively more impaired including: Rays Crossing Tributary, Cotton Run, Beaver Meadow Creek, and Farmers Stream.

6.3 MACROINVERTEBRATE AND HABITAT ASSESSMENT

6.3.1 Macroinvertebrate Sampling Methods

Data from macroinvertebrate sampling at each of the 10 sites in the Little Blue River Watershed and the reference site were used to calculate an index of biotic integrity. Aquatic macroinvertebrates are important indicators of environmental change. The macroinvertebrate community composition reflects water quality. Research shows that different macroinvertebrate orders and families react differently to pollution sources. Thus, indices of biotic integrity are valuable because aquatic biota integrate cumulative effects of sediment and nutrient pollution (Ohio EPA, 1995)

Macroinvertebrates were collected during base flow conditions on July 30-31, 2003 using the multihabitat approach detailed in the USEPA Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers, 2nd ed. (Barbour et al. 1999). This method was supplemented by qualitative picks from substrate and by surface netting. Two researchers collected macroinvertebrates for 20 minutes and a third researcher aided in the collection for 10 minutes for a total of 50 minutes of collection effort. The macroinvertebrate samples were processed using the laboratory processing protocols detailed in the same manual. Organisms were identified to the family level. The family-level approach was used because: 1) it would allow data collected in this study to be comparable to that collected by IDEM; 2) it allows for increased organism identification accuracy; 3) several studies support the adequacy of family-level analysis (Furse et al., 1984; Ferraro and Cole, 1995; Marchant, 1995; Bowman and Bailey, 1997; Waite et al., 2000).

Macroinvertebrate data were used to calculate the family-level Hilsenhoff Biotic Index (HBI). The HBI uses the macroinvertebrate community to assess the level of organic pollution in a stream. The HBI is based on the premise that different families of aquatic insects possess different tolerance levels to organic pollution. Hilsenhoff assigned each aquatic insect family a tolerance value from 1 to 9; those families with lower tolerances to organic pollution were assigned lower values, while those families that were more tolerant of organic pollution were assigned higher values. Calculation of the HBI involves applying assigned macroinvertebrate family tolerance values to all taxa that have an assigned HBI tolerance value, multiplying the number of organisms present by their family tolerance value, summing the products, and dividing by the total number of organisms present (Hilsenhoff, 1988). Benthic communities dominated by organisms that are tolerant of organic pollution will exhibit higher HBI scores compared to benthic communities dominated by intolerant organisms.

In addition to the HBI, macroinvertebrate results were analyzed using a modified version of IDEM's macroinvertebrate Index of Biotic Integrity (mIBI) (IDEM, unpublished). IDEM's mIBI is a multi-metric (10 metrics) index designed to provide a complete assessment of a stream's biological integrity. Karr and Dudley (1981) define biological integrity as "the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization compared to the best natural habitats within the region". It is likely that this definition of biological integrity is what IDEM means by biological integrity as well. IDEM developed the mIBI using five years of wadeable data collected in Indiana. The data were lognormally distributed for each of the ten metrics. Each metric's lognormal distribution was then pentasected with scoring based on five categories using 1.5 times the interquartile range around the geometric mean. Table 59 lists the eight scoring metrics used in this study and the value or range of values associated with the classification scores. The mean of the eight classification scores for each metric is the mIBI score. Classification score are 0, 2, 4, 6, and 8. mIBI scores of 0-2 indicate the sampling site is severely impaired; scores of 2-4 indicate the site is moderately impaired; scores of 4-6 indicate the site is slightly impaired; and scores of 6-8 indicate that the site is non-impaired.

Table 59. Benthic macroinvertebrate scoring criteria used by IDEM in the evaluation of streams in Indiana.

	SCORING CRITERIA FOR THE FAMILY LEVEL MACROINVERTEBRATE INDEX OF BIOTIC INTEGRITY (mIBI)USING PENTASECTION AND CENTRAL TENDENCY ON THE LOGARITHMIC TRANSFORMED DATA DISTRIBUTIONS OF THE 1990-1995 RIFFLE KICK SAMPLES				
	CLASSIFICATION SCORE				
	0	2	4	6	8
Family Level HBI	>5.63	5.62-5.06	5.05-4.55	4.54-4.09	<4.08
Number of Taxa	<7	8-10	11-14	15-17	>18
Percent Dominant Taxa	>61.6	61.5-43.9	43.8-31.2	31.1-22.2	<22.1
EPT Index	<2	3	4-5	6-7	>8
EPT Count	<19	20-42	43-91	92-194	>195
EPT Count To Total Number of Individuals	<0.13	0.14-0.29	0.30-0.46	0.47-0.68	>0.69
EPT Count To Chironomid Count	<0.88	0.89-2.55	2.56-5.70	5.71-11.65	>11.66
Chironomid Count	>147	146-55	54-20	19-7	<6

Where: 0-2 = Severely Impaired, 2-4 = Moderately Impaired, 4-6 = Slightly Impaired, 6-8 = Nonimpaired

6.3.2 Macroinvertebrate Results

In general, the Little Blue River mainstem sites (Lower, Middle, and Upper Little Blue River) supported more diverse and more pollution intolerant communities than the Little Blue River Headwaters and the Little Blue River tributaries. Taxa richness (number of taxa) was similar among the Little Blue River mainstem and tributary sites. Manilla Branch (Site 3) possessed the highest taxa richness (20 species); however, pollution tolerant species dominated the community at this site. Pollution tolerant families dominated the Little Blue River Headwaters (Site 10), Little Gilson Creek (Site 9), and Cotton Run (Site 4) sites. The Headwaters (Site 10) and Little Gilson Creek (Site 9) sites possessed high numbers of individuals from the families *Chironomidae* and *Corixidae*, two high pollution tolerant families, and low numbers of individuals from the more sensitive EPT families. Members of the pollution tolerant families *Chironomidae* and *Asellidae* dominated the macroinvertebrate community at Cotton Run (Site 4). The Lower Little Blue River (Site 1), Middle Little Blue River (Site 5), Upper Little Blue River (Site 8), and Beaver Meadow Creek (Site 6) supported the lowest number of taxa (16 species). The three mainstem sites possessed more sensitive taxa and greater EPT index scores compared to other sites. Members of the EPT taxa dominated the benthic community at the Middle Little Blue River (Site 5) accounting for nearly 80% of the total sub-sample. Additionally, this site was the only one to harbor members of the Plecopteran order, which is arguably the most sensitive order. (Macroinvertebrate community sample collection occurred during the fall at this site, which is typically when members of the Plecopteran order are more prevalent.) Members of the Plecopteran order are extremely intolerant to sediment and organic pollution.

When the macroinvertebrate communities at each sampling site are evaluated using the HBI, the HBI scores reflect the relative differences in macroinvertebrate communities previously noted (Tables 60 and 61). The Lower (Site 1), Middle (Site 5), and Upper Little Blue River (Site 8) mainstem sites along with Rays Crossing (Site 2), Farmers Stream (Site 7), and Beaver Meadow Creek (Site 6) had lower (better) HBI scores compared to the Little Blue River Headwaters, Little Gilson Creek (Site 9), Manilla Branch (Site 3), and Cotton Run (Site 4). HBI scores at the Lower (Site 1), Middle (Site 5), and Upper Little Blue River (Site 8), Rays Crossing (Site 2), Farmers Stream (Site 7), and Beaver Meadow Creek (Site 6) sites suggest that the stream possessed good to excellent water quality and that organic pollution was unlikely to some probable. Conversely, HBI scores indicate that water quality in Cotton Run (Site 4) was fair, while Manilla Branch (Site 3) and Little Gilson Creek (Site 9) possessed fairly poor water quality and the Little Blue River Headwaters contained poor water quality. HBI scores also suggest that the level of organic pollution in these streams is fairly substantial to very high. Conn's Creek only possessed fair water quality when assessed with the HBI.

Table 60. Family-level Hilsenhoff Biotic Index at the Little Blue River Watershed sampling sites.

Site	HBI
Lower Little Blue River (Site 1)	4.8
Rays Crossing (Site 2)	4.2
Manilla Branch (Site 3)	5.9
Cotton Run (Site 4)	5.4
Middle Little Blue River (Site 5)	3.1
Beaver Meadow Creek (Site 6)	4.9
Farmers Stream (Site 7)	4.2
Upper Little Blue River (Site 8)	4.8
Little Gilson Creek (Site 9)	6.2
Little Blue Rivers Headwaters (Site 10)	6.6
Conn's Creek (Reference Site)	5.4

Table 61. Water quality correlation to Hilsenhoff Biotic Index score.

Family Biotic Index	Water Quality	Degree of Organic Pollution
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very good	Possible slight organic pollution
4.26-5.00	Good	Some organic pollution probable
5.01-5.75	Fair	Fairly substantial pollution likely
5.76-6.50	Fairly poor	Substantial pollution likely
6.51-7.25	Poor	Very substantial pollution likely
7.26-10.00	Very poor	Severe organic pollution likely

Generally, the HBI scores are consistent with the results of the water chemistry sampling effort. Little Gilson Creek (Site 9), Manilla Branch (Site 3), Cotton Run (Site 4), and the Little Blue River Headwaters (Site 10) exhibited the highest (worst) HBI scores suggesting high levels of organic pollution in these streams. All of these streams exhibited elevated concentrations of total Kjeldahl nitrogen relative to the other tributary sites, and all sites, except the Headwaters (Site 10), exhibited elevated total phosphorus concentrations relative to other tributary sites. Total Kjeldahl nitrogen is a measure of the amount of ammonia-nitrogen and organic nitrogen (particulate) in the water column. This evidence suggests that organic matter in these streams may be impairing their biological integrity. Organic matter accumulation was also observed during site inspections at these locations.

The mIBI scores highlight the difference between the macroinvertebrate communities found at the Middle Little Blue River (Site 5), Farmers Stream (Site 7), and Upper Little Blue River (Site 8) sites and Manilla Branch (Site 3), Cotton Run (Site 4), and Little Gilson Creek (Site 9) sites. In general, the biotic integrity of the macroinvertebrate communities in the middle and upper portions of the mainstem of the Little Blue River and Farmers Stream are less impaired than it is along the lower portions of the stream and many of its tributaries. The results of the macroinvertebrate survey clearly demonstrate this difference (Table 62). Middle and Upper Little

Blue River mainstem and Farmers Stream mIBI scores suggest that the macroinvertebrate communities in Farmers Stream and the middle and upper portions of the Little Blue River are unimpaired to slightly impaired, while the Lower Little Blue River and remaining tributary mIBI scores indicate the macroinvertebrate communities in these streams are slightly to moderately impaired (Table 62). Most indices of biotic integrity are developed to ensure that there is a statistically significant difference between impairment categories (Karr and Chu, 1999). As such, the macroinvertebrate survey results suggest there is a significant difference between the biological integrity of the macroinvertebrate communities in Farmers Stream and the Middle Little Blue River and the macroinvertebrate communities in the Lower and Headwaters portions of the Little Blue River and most of its tributaries.

Table 62. Metric classification scores and mIBI score for the Little Blue River Watershed sampling sites as sampled July 30-31, 2003.

Site	HBI	No. Taxa	% Dom. Taxa	EPT Index	EPT Count	EPT Ct./ Total Ct.	EPT Ab./ Chir. Ab.	Chir. Count	mIBI Score
Lower Little Blue River (1)	4	6	6	4	4	4	2	4	**4.25**
Rays Crossing (2)	6	8	8	4	2	2	4	8	**5.25**
Manilla Branch (3)	0	8	6	0	0	0	0	8	**2.75**
Cotton Run (4)	4	6	6	4	2	2	0	4	**3.25**
Middle Little Blue River (5)	8	6	6	8	6	8	8	8	**7.25**
Beaver Meadow Creek (6)	4	6	2	2	4	6	8	8	**5.0**
Farmers Stream (7)	6	8	8	4	4	4	6	8	**6.0**
Upper Little Blue River (8)	2	6	8	6	4	6	4	6	**5.5**
Little Gilson Creek (9)	0	6	6	0	0	0	0	8	**2.5**
Headwaters (10)	0	6	8	4	2	4	6	8	**4.75**
Conn's Creek (Reference)	2	8	4	4	2	4	8	8	**5.0**

Where: 0-2 = Severely Impaired, 2-4 = Moderately Impaired, 4-6 = Slightly Impaired, 6-8 = Non-impaired

The mIBI scores support the hypothesis that poor water quality in the lower portion of the Little Blue River (Site 1), Little Gilson Creek (Site 9), Manilla Branch (Site 3), and Cotton Run (Site 4) may be impairing these streams' biological integrity. Elevated nutrient and total suspended solid concentrations and loads were recorded at the Lower Little Blue River and Manilla Branch during both base and storm flow sampling. Little Gilson Creek possessed the highest nitrate-nitrogen concentrations during both base and storm flow, and Cotton Run loaded the highest amount of sediment and sediment-attached pollutants per unit area during base flow. These same waterbodies exhibited mIBI scores indicating the greatest biotic integrity impairment of the watershed streams. These results are consistent with results observed in Ohio (Ohio EPA, 1999).

Although these criteria are not part of the Indiana Administrative Code, IDEM hints that it may be using mIBI scores to determine whether a waterbody is meeting its aquatic life use designation. (Under state law, all waters of the state, except for those noted as Limited Use in the Indiana Administrative Code, must be capable of supporting recreational and aquatic life uses.) In the 2000 305(b) report, IDEM suggests that those waterbodies with mIBI scores less than 2 are considered non-supporting for aquatic life use. Similarly, waterbodies with mIBI scores between 2 and 4 are considered to be partially supporting for aquatic life use. Under federal law, waters that do not meet their designated uses must be placed on the 303(d) list and remediation/restoration plans (Total Maximum Daily Load plans) must be developed for these waters. Figure 69 displays the Little Blue River Watershed mIBI scores based on the macroinvertebrate sampling effort with respect to the suggested IDEM criteria. The mIBI scores indicate that all the watershed streams are at least partially supporting of aquatic life use. The three sites that appear to only provide partial support of the aquatic life use designation are Manilla Branch (Site 3), Cotton Run (Site 4), and Little Gilson Creek (Site 9).

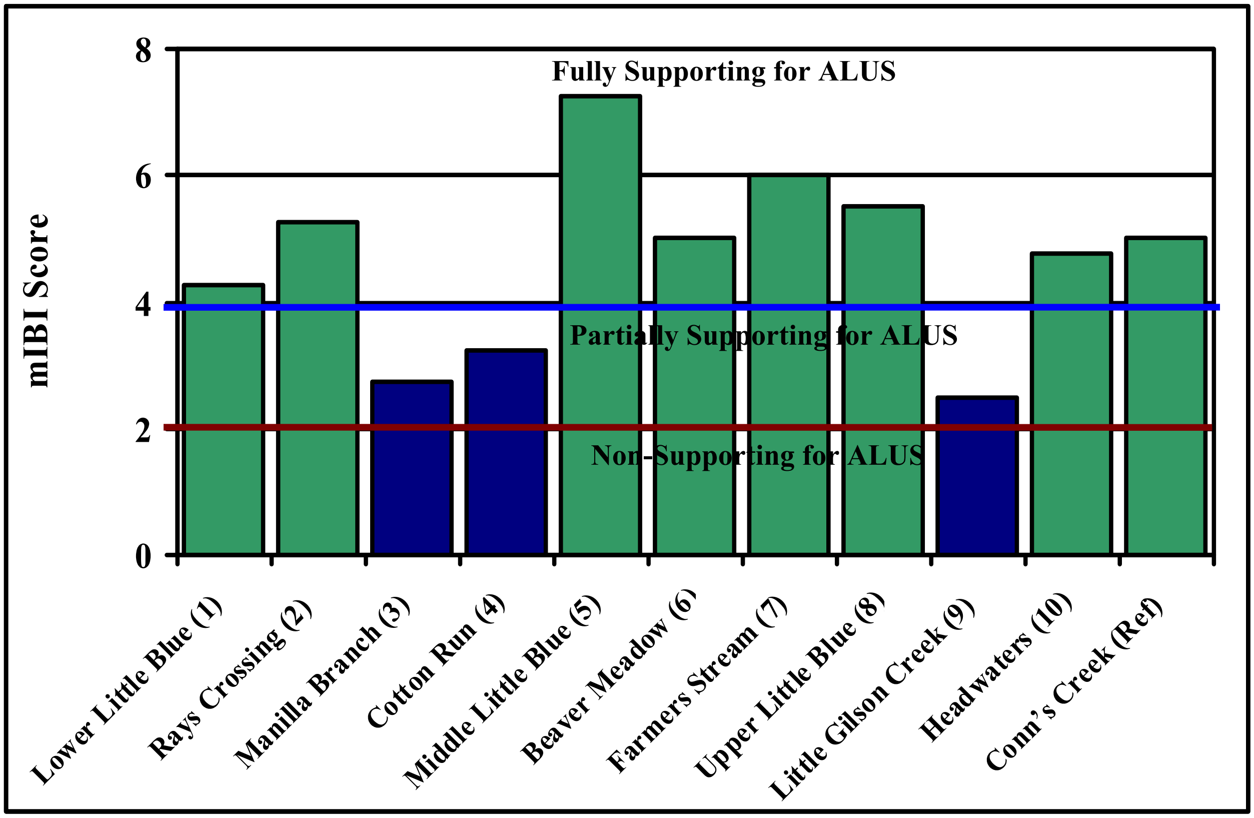


Figure 69. Aquatic life use support (ALUS) assessment based on macroinvertebrate community collection.

6.3.3 Habitat Sampling Methods

Physical habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1995). Various attributes of the stream and riparian zone habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates; amount and quality of instream cover; channel morphology; extent and quality of riparian vegetation; pool, run, and riffle development and quality; and gradient are some of the metrics used to determine the QHEI score. The QHEI score ranges from 20 to 100.

Substrate type(s) and quality are important factors of habitat quality and the QHEI score is partially based on these characteristics. Sites that have greater substrate diversity receive higher scores as they can provide greater habitat diversity for benthic organisms. The quality of substrate refers to the embeddedness of the benthic zone. Small particles of soil and organic matter will settle into small pores and crevices in the stream bottom. Many organisms can colonize these microhabitats, but high levels of silt in a streambed can result in the loss of habitat within the substrate. Thus, sites with heavy embeddedness and siltation receive lower QHEI scores for the substrate metric.

Instream cover, another metric of the QHEI, represents the type(s) and quantity of habitat provided within the stream itself. Examples of instream cover include woody logs and debris, aquatic and overhanging vegetation and root wads extending from the stream banks. The channel morphology metric evaluates the stream's physical development with respect to habitat diversity. Pool and riffle development within the stream reach, the channel sinuosity and other factors that represent the stability and direct modification of the site are evaluated to comprise this metric score.

A wooded riparian buffer is a vital functional component of riverine ecosystems. It is instrumental in the detention, removal, and assimilation of nutrients. According to the Ohio EPA (1999), riparian zones govern the quality of goods and services provided by riverine ecosystems. Riparian zone and bank erosion were examined at each site to evaluate the quality of the buffer zone of a stream, the land use within the floodplain that affects inputs to the waterway, and the extent of bank erosion, which can reflect insufficient vegetative stabilization of the stream banks. For the purposes of the QHEI, a riparian buffer is a zone that is forest, shrub, swamp, or woody old field vegetation. Typically, weedy, herbaceous vegetation does not offer as much infiltration potential as woody components and does not represent an acceptable riparian zone type for the QHEI (Ohio EPA, 1989).

The fifth QHEI metric evaluates the quality of pool/glide and riffle/run habitats in the stream. These zones in a stream, when present, provide diverse habitat and in turn can increase habitat quality and availability. The depth of pools within a reach and the stability of riffle substrate are some factors that affect the QHEI score in this metric.

The final QHEI metric evaluates the topographic gradient in a stream reach. This is calculated using topographic data. The score for this metric is based on the premise that both very low and very high gradients will have negative effects on habitat quality and the biota in the stream. Moderate gradients receive the highest score, 10, for this metric.

The QHEI is used to evaluate the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. QHEI scores from hundreds of stream segments in Ohio have indicated that values greater than 60 are *generally* conducive to the existence of warmwater faunas. Scores greater than 75 typify habitat conditions that have the ability to support exceptional warmwater faunas (Ohio EPA, 1999). IDEM indicates that QHEI scores above 64 suggest the habitat is capable of supporting a balanced warmwater community; scores between 51 and 64 are only partially supportive of a stream's aquatic life use designation, while scores less than 51 are deemed non-supporting the stream's aquatic life use designation (IDEM, 2000).

6.3.4 Habitat Results

Table 63 lists the QHEI scores for the Little Blue River Watershed sites. The Upper Little Blue River (Site 8) and Manilla Branch (Site 3) sites received the highest score, 63. Stable substrate, well developed channel morphology, available instream and canopy cover, and developed pools and riffles characterize these reaches. Little Gilson Creek (Site 9) received the lowest score, 30 of a possible 100. Poor instream and canopy cover, lack of well developed pools and riffles, and poor substrate limited the available habitat at this reach. Generally, the Middle (Site 5) and Upper (Site 8) portions of the Little Blue River, Rays Crossing (Site 2), Beaver Meadow Creek (Site 6), and the Headwaters (Site 10) scored higher in all metrics than the Lower Little Blue River (Site 1), Cotton Run (Site 4), and Little Gilson Creek (Site 9) reaches. The low QHEI scores suggest that these three reaches may not be capable of supporting healthy aquatic communities.

Table 63. QHEI scores for the Little Blue River Watershed sampling sites as sampled July 30-31, 2003.

Site	Substrate Score	Cover Score	Channel Score	Riparian Score	Pool Score	Riffle Score	Gradient Score	Total Score
Maximum Possible Score	20	20	20	10	12	8	10	**100**
Lower Little Blue River (1)	11	8	12	2	0	0	10	**43**
Rays Crossing (2)	8	12	14	4	8	2	10	**58**
Manilla Branch (3)	13	11	14	5	7	3	10	**63**
Cotton Run (4)	13	12	5	2	3	0	10	**45**
Middle Little Blue River (5)	11	11	8	6	4	5	10	**55**
Beaver Meadow Creek (6)	14	11	12	6	9	0	8	**60**
Farmers Stream (7)	7	9	17	4	7	5	4	**53**
Upper Little Blue River (8)	16	10	16	4	9	4	4	**63**
Little Gilson Creek (9)	1	6	8	8	2	1	8	**30**
Headwaters (10)	14	8	11	4	4	5	10	**56**
Conn's Creek (Reference)	13	14	12	4	7	5	8	**63**

At some sites, the habitat scores do not reflect the same pattern observed in the water chemistry and macroinvertebrate community data. Little Gilson Creek (Site 9) and Cotton Run (Site 4) are in worse condition than many of the other tributaries; Little Gilson Creek possessed the highest nitrate-nitrogen concentrations and loaded the highest amount of nitrate-nitrogen per unit area during both base and storm flow. Likewise, Cotton Run loaded the highest amounts of sediment and sediment-attached pollutants per unit area during base flow. Poor habitat quality and suboptimum water quality in Little Gilson Creek (Site 9) and Cotton Run (Site 4), combined with factors not measured during this study, created an inhospitable environment for macroinvertebrates. The mIBI scores at these sites reflect this. It is important to note that Little Gilson Creek (Site 9) has been heavily modified. It is likely that changes in the stream's hydrology also play a large role in shaping the macroinvertebrate community in this stream. The Upper Little Blue River (Site 8) and Manilla Branch (Site 3) reaches possessed the best instream and riparian habitat as measured by the QHEI. However, both sites exhibited relatively poor water chemistry with respect to other sites in the watershed. In the Upper Little Blue River, habitat quality helped create an environment suitable for a well-balanced, pollution intolerant macroinvertebrate community. The site's relatively high mIBI score suggests the site does support a macroinvertebrate community that is of high enough quality to meet the stream's aquatic life use designation. In contrast, the Manilla Branch (Site 3) possessed elevated dissolved nutrient concentrations and contained a pollution tolerant macroinvertebrate community that lacked members of the EPT taxa. It is likely that poor water quality, or factors that were not measured during this study, outweighs the diverse habitat observed in the Manilla Branch; the poor mIBI score at this site supports this idea.

6.3.5 Macroinvertebrate and Habitat Site Discussion

mIBI and QHEI scores for each sampling site are given in Tables 62 and 63. Detailed QHEI and mIBI results are included in Appendix G and H, respectively. The mIBI scores ranged from 2.5 at Little Gilson Creek (Site 9) to 7.25 at the Middle Little Blue River (Site 8). All QHEI scores except Manilla Branch (Site 3; 63), the Upper Little Blue River (Site 8; 63), Conn's Creek (Reference Site; 63), and Beaver Meadow Creek (Site 6; 60) fell below 60, the level conducive to the existence of warmwater fauna (Ohio EPA, 1999). Figure 70 shows cross-sections of the stream sampling sites. Nearly all of the sites have relatively steep banks, indicative of streambank erosion and/or stream modification and channelization. A site-by-site description of particular characteristics that contribute to the mIBI and QHEI scores at each site follows.

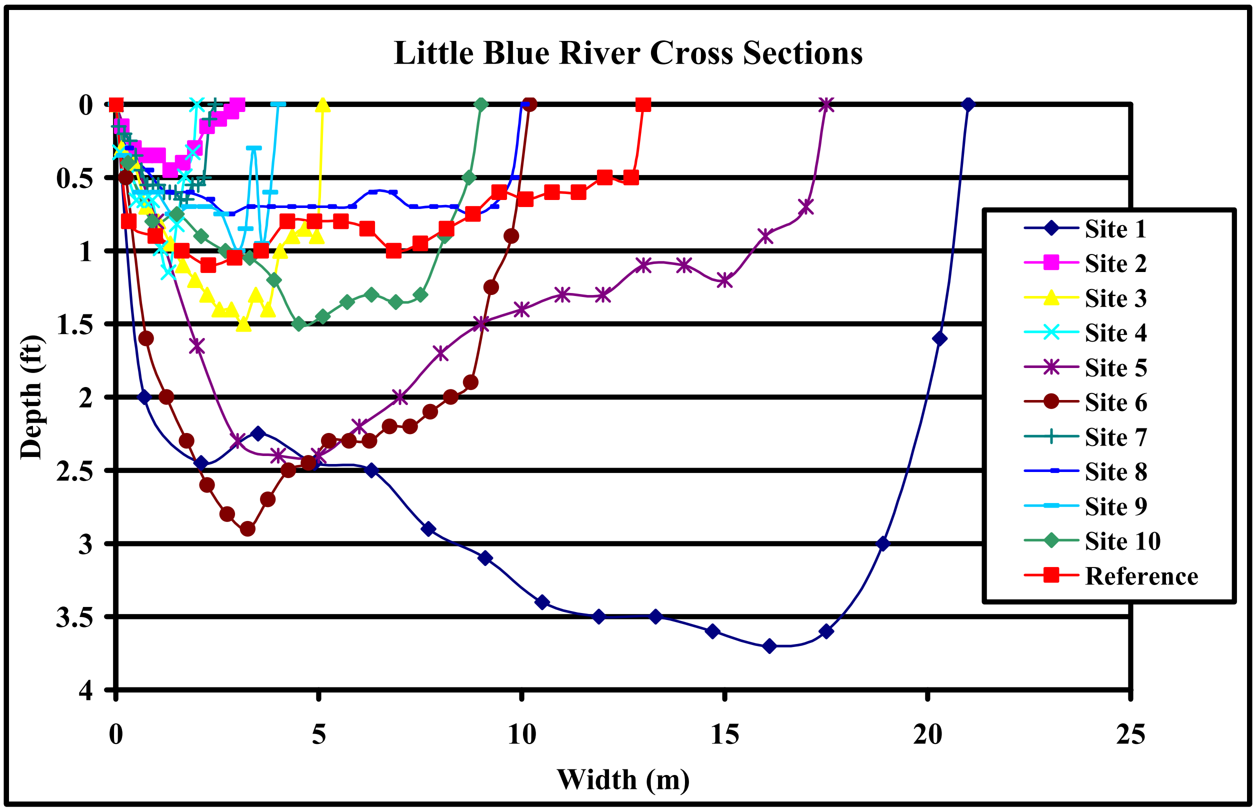


Figure 70. Cross-sections of Little Blue River Watershed streams at sampling locations.

Lower Little Blue River (Site 1). The QHEI score was 43 out of a possible 100 points. Substrate composition at this site was predominately muck and silt with some gravel. Moderate silt cover was present, while substrate embeddedness was low. Instream conditions were fair with high channel stability, low substrate embeddedness, and limited riffle/run development. Overhanging vegetation, aquatic macrophytes, woody debris, boulders, and rootwads provided sparse instream cover. The site was surrounded by public parkland associated with the Shelby County 4-H

Fairgrounds and Kennedy Park, a public park including playground equipment, a streamside boardwalk, and a baseball diamonds. The riparian zone was narrow extending up to nine feet (three meters) from either streambank. Sparse shrubs and mowed grass vegetated the riparian zone. Bank stability was low with heavy or severe erosion. No sinuosity was observed in the stream reach with recent to no recovery from channelization likely due to the size of the channel. The stream at this site possessed the widest stream channel of any in the Little Blue River Watershed (69.8 feet or 21.0 meters; Figure 70). The mIBI score for this site was 4.25 out of a possible 8, indicating that the stream is "slightly impaired." Members of the moderately tolerant family *Heptageniidae* and the highly tolerant family *Chironomidae* dominated the macroinvertebrate community. High numbers of Chironomids, a high (poor) HBI score, and low density and diversity of members of the EPT taxa characterized the macroinvertebrate community at the Lower Little Blue River site.

Figure 71. Site 1 sampling location on the Little Blue River.

Rays Crossing Tributary (Site 2). This site received a QHEI score of 58 of a possible 100. The substrate composition at the site was a combination of muck and gravel. Substrate embeddedness and bank stability were moderate. Overhanging vegetation, shallows, deep pools, and logs or woody debris provided moderate levels of instream cover. Moderate sinuosity was present with no evidence of any prior channelization. The riparian zone extended between fifteen to thirty feet (4.6 to 9.1 meters) on either side of the streambank. Trees and shrubs dominated the riparian vegetation. Both stream banks were moderately eroded. Pool/ riffle development was fair with the presence of deep pools, which possessed a variety of flow regimes. The mIBI score was 5.25, which is indicative of the "slightly impaired" condition at this site. The most abundant macroinvertebrates at this site were members of the moderately tolerant *Coleopteran* family *Elmidae*, the *Ephemeropteran* family *Heptageniidae*, the *Hemipteran* family *Veliidae*, and the highly pollution tolerant *Isopodan* family *Asellidae*. Low EPT taxa density and diversity, high taxa richness, and balanced diversity characterized the macroinvertebrate community at this site.

Figure 72. Site 2 sampling location on Rays Crossing Tributary.

Manilla Branch (Site 3). This site received the highest QHEI score of any of the Little Blue River Watershed sites, 63 of a possible 100. Sand dominated the substrate; cobble, muck, and silt were also present. Silt levels were low with low levels of substrate embeddedness. Overhanging vegetation, aquatic macrophytes, logs and woody debris, and shallows provided moderate levels of instream cover. Moderately well developed pools and riffles with low embeddedness provide additional habitat at this site. The stream possessed moderate sinuosity with no observed evidence of channelization. The riparian buffer was narrow extending between fifteen and thirty feet (five and ten meters) on either side of the stream. Trees, shrubs, and mowed grass were the predominant vegetation types in the riparian buffer. The stream is considered to be "moderately impaired" with a mIBI score of 2.75. Given the relatively high QHEI score, poor water quality likely plays a role in impairing the biotic community at this site. The macroinvertebrate community composition was dominated by highly pollution tolerant members of the orders *Gastropoda* and *Isopoda*. High taxa richness, a high (poor) HBI score, and low numbers and diversity of pollution intolerant EPT taxa characterize the macroinvertebrate community in the Manilla Branch reach.

Figure 73. Site 3 sampling location on the Manilla Branch.

Cotton Run (Site 4). Cotton Run received a QHEI score of 45. Gravel and sand dominated the substrate; muck and cobble were also present. The substrate was moderately embeddedness with normal levels of silt cover. Overhanging vegetation, shallows, rootwads, aquatic macrophytes, logs, and woody debris provided moderate instream cover. Heavy to severe bank erosion was present throughout the reach creating low channel stability. Channelization was apparent with County Road 1000 West running along the left bank of the stream. Stream sinuosity was low with poor pool/riffle development. The riparian buffer was limited on one side by the presence of County Road 1000 West; along the other bank, the riparian zone only extended only nine to thirty feet (three to ten meters) beyond the stream. The riparian vegetation was composed of trees, shrubs, and mowed grass. Pool/ riffle development was poor; no deep pools were observed at this site, while shallow, gravel and sand riffles predominated. The mIBI score (3.25) indicated that the macroinvertebrate community was moderately impaired. A high HBI score, low density and diversity of EPT taxa, and high numbers of tolerant members of the *Dipteran* family *Chironomidae* characterize the community at the Cotton Run reach.

Figure 74. Site 4 sampling location on Cotton Run.

Middle Little Blue River (Site 5). This site received a QHEI score of 55 out of a possible 100 points. Sand and gravel dominated the substrate at this reach of the Little Blue River; cobble, muck, and detritus were also present at this site. Silt levels were moderate with extensive substrate embeddedness. Undercut banks, shallows, rootwads, and logs and woody debris provided moderate levels of instream cover. Channel sinuosity was minimal due to stream channelization around the bridge. The stream possessed poor pool/riffle development and moderate channel stability. Wide riparian zones vegetated with young trees and shrubs extend 150 feet (45.7 meters) on both streambanks. Pool development was poor and most of the reach's pools were moderately deep with only one flow regime. The site also possessed moderate riffle development. The mIBI score indicated that this site was unimpaired scoring the highest of any of the Little Blue River Watershed sites (7.25). (The macroinvertebrate sample was collected from this site in late October, the time of the year when community diversity is normally the highest.) The macroinvertebrate community was comprised of highly intolerant EPT species, specifically members of the highly pollution intolerant *Plecopteran* families *Capniidae*, *Chloroperlidae*, and *Taeniopterygidae* and of the moderately pollution tolerant *Trichopteran* family *Hydropsychidae*. EPT taxa composed nearly 80% of the macroinvertebrate community. A low (good) HBI score, high taxa richness, high density and diversity of intolerant EPT taxa, a low density of pollution tolerant members of the family Chironomidae characterize the macroinvertebrate community at this site.

Figure 75. Site 5 sampling location on the Little Blue River.

Beaver Meadow Creek (Site 6). Beaver Meadow Creek received the second highest QHEI score (60) of any of the Little Blue River Watershed streams. Sand dominated the substrate composition with cobble, gravel, and boulders also present. Silt levels were low with low to moderate substrate embeddedness. Shallows, deep pools, root wads, and woody debris provided moderate levels of instream cover. The banks were experiencing moderate to heavy erosion. No channelization was observed at the site; however, sinuosity of the stream was very limited. The riparian buffer was wider along the left bank reaching a width greater than 15 feet (4.6 meters). The left riparian zone was narrower only reaching a distance of three feet (0.9 meters). The vegetation in the riparian zone was predominantly forest and shrubs. Pool/riffle development was fair to poor. The mIBI score was 5.0 indicating that the community was slightly impaired. The macroinvertebrate community possessed high taxa richness, but was dominated by pollution tolerant families. Over 50% of the macroinvertebrates collected at the site were from the *Ephemeropteran* family *Heptageniidae*, a moderately pollution tolerant family.

Figure 76. Site 6 sampling location on Beaver Meadow Creek.

Farmers Stream (Site 7). The Farmers Stream reach scored a QHEI score of 55 of a possible 100 points. Substrate composition was a mixture of sand and muck with the presence of cobble, gravel, and sand in the riffles. The level of substrate embeddedness was moderate. Instream cover was limited containing a mixture of overhanging tree branches, shallow stream regions, and deep pools. Stream banks were experiencing moderate to severe erosion; however, the banks remained moderately stable. The stream site had a high level of sinuosity with no evidence of channelization. The riparian buffer along both sides of the streambed was narrow to very narrow only extending up to three feet (0.9 meters) away from the streambanks. The riparian vegetation along the stream consisted of a mixture of trees, shrubs, dead grasses, and mowed residential lawn. Pool/riffle development at the site was good with the presence of deep pools and stable, boulder and cobble riffles. The mIBI score (6.0) was the second highest of any of the stream reaches surveyed. The macroinvertebrate community consisted of a highly diverse group of families, most of which were intolerant to pollution. The predominant macroinvertebrates found at the site were members of the Coleopteran family *Elmidae*, the Trichopteran family *Hydropsychidae*, and *Ephemeropteran* family *Baetidae*.

Figure 77. Site 7 sampling location on Farmers Stream.

Upper Little Blue River (Site 8). The QHEI score for this stream reach was 63, the highest of any of the Little Blue River Watershed sites. The substrate composition was a blend of sand and gravel with a low level of substrate embeddedness. Boulder, cobble, muck, silt, and artificial substrates were also present throughout the reach. The site contained sparse to moderate instream cover consisting of overhanging vegetation, deep pools, woody debris, and boulders present throughout the reach. Erosion at the site was moderate to heavy along both streambanks; however, the banks were relatively stable. No apparent channelization was observed and the stream channel was relatively straight with no sinuosity. The riparian buffer along each bank was limited, extending up to ten feet (three meters) from the streambanks. Pool/ riffle development at the site was moderately poor with only one riffle and one deep pool observed; the remainder of the site was predominantly run habitat. The macroinvertebrate community was slightly impaired with a mIBI score of 5.5. The macroinvertebrate community contained representatives from the moderately tolerant *Trichopteran* family *Hydropsychidae*, the *Ephemeropteran* family *Baetidae*, and the *Dipteran* family *Simuliidae*.

Figure 78. Site 8 sampling location on the Little Blue River.

Little Gilson Creek (Site 9). This site scored the lowest of the stream reaches on the QHEI survey with a score of 30. Factors affecting the low habitat score included the lack of substrate diversity, poor instream cover, lack of developed channel morphology, and poorly developed pool and riffle sequences. The streambed was predominantly muck and silt with approximately 20% of the site covered by of gravel and cobble. Stream substrate embeddedness was extensive with heavy silt cover. The site contained sparse instream cover. The instream cover that was present was comprised of overhanging vegetation, shallow water, and woody debris. Erosion along the stream banks was moderate, leaving the banks moderately stable. Channel sinuosity was low with evidence of recovering from prior channelization (Figure 79). The riparian zone along the banks was very narrow extending to a distance of 10 feet (3.0 meters) to 30 feet (9.1 meters). Vegetation in the riparian buffer zone was a forest mixture of young trees and shrubs. Pool and riffle development at the site was poor with only one unstable, pea gravel riffle and no deep pools observed. The mIBI score (2.5) for the site was the lowest of the sites surveyed. Highly pollution tolerant macroinvertebrate families dominated the site including the *Hemipteran* family *Coxidae* and individuals from the order *Planaria*. Planarians are very intolerant of low oxygen conditions but tolerant to most other environmental stresses. Additionally, low density and diversity of highly pollution intolerant species of the EPT families contributed to the poor mIBI score.

Figure 79. Site 9 sampling location on Little Gilson Creek.

Little Blue River Headwaters (Site 10). The Headwaters site scored a 56 on the QHEI survey. Gravel was the dominant substrate component; cobble, muck, and sand were also present in the riffles and runs. The level of substrate embeddedness was low with a moderate amount of silt cover. Instream cover was sparse to moderate and comprised of overhanging vegetation, shallow water, rootwads, and aquatic macrophytes. Erosion along the banks was moderate, in part controlled by grasses growing on the banks. Bank stability was also moderate. The surrounding land use was dominated by row crop agriculture. The riparian buffer zone was classified as very narrow with widths of three to ten feet (0.9 to 3.0 meters) along the north bank. The south bank buffer zone was more extensive reaching a distance of 150 feet (45.7 meters). Vegetation within the riparian zones along both banks was dominated by grass near the bridge and by forested land along the remainder of the reach. Pool and riffle development metric scores were low because the reach lacked deep pools and possessed unstable, pea gravel riffles. The macroinvertebrate community was slightly impaired, receiving a mIBI score of 4.75. The highly pollution tolerant *Hemipteran* family *Coxidae* and moderately pollution tolerant *Ephemeropteran* family *Caenidae* dominated the macroinvertebrate community. Although the community possessed high taxa richness, the presence of moderately tolerant families and the absence of pollution intolerant EPT families indicated that the community was slightly impaired.

Figure 80. Site 10 sampling location on the Little Blue River.

Conn's Creek (Reference Site). The QHEI score for the site was 63. Sand and gravel were the dominant substrate types present with cobble and muck also present. The level of instream cover was moderate consisting of shallow water, deep pools, rootwads, aquatic macrophytes, and woody debris. The level of erosion along the banks was moderate, leaving the banks relatively stable. Sinuosity of the stream channel was low with no evidence of prior channelization. Substrate embeddedness was low with a normal amount of silt cover. Row crop agriculture and residential open spaces were the dominant land use types surrounding this site. The riparian buffer zone extended up to 30 feet (9.1 meters) from either streambank. Riparian vegetation was a mixture comprised of mostly shrubs and trees. Pool and riffle development was good to fair with the presence of deep pools and well developed riffles. The macroinvertebrate community was classified as "slightly impaired" obtaining a mIBI score of 5.0. Members of the Coleopteran family *Elmidae* and the *Ephemeropteran* family *Heptageniidae* dominated the macroinvertebrate community.

Figure 81. Reference site sampling location on Conn's Creek.

6.3.6 Macroinvertebrate and Habitat Discussion

The overall evaluation of biotic health and habitat quality in the Little Blue River Watershed indicates that these waterways are slightly to moderately degraded. Many of the study sites lacked at least one of the key elements of natural, healthy stream habitats. These missing key elements limit the functionality of these systems. The QHEI evaluations from each site describe moderate to poor substrate quality throughout streams in the Little Blue River Watershed. Additionally, QHEI scores generally reflected the poor pool and riffle development in watershed streams; there was almost a complete absence of sufficient riffle development within the stream channels, as well as very poor pool habitat in some sites. Channel alterations and minimal riparian buffer zones reduce the Little Blue River resilience to agricultural runoff. These factors are critical for habitat diversity and biological integrity in the stream ecosystems. In the Little Blue River Watershed slightly to moderately poor mIBI scores reflected the slightly degraded habitat conditions.

Heavy sediment loading was an apparent factor in the degradation of substrate quality in the study streams. Several of the sites along the Little Blue River (Sites 1, 5, and 8), Little Gilson Creek (Site 9), and Rays Crossing Tributary (Site 2) have experienced considerable silt sedimentation levels. Extensive substrate embeddedness severely limits habitat diversity within the stream channel by filling in and closing off porous areas that offer refuge for a variety of aquatic organisms. This heavy sediment loading is reflected in the poor substrate scores of the QHEI evaluation. The range of substrate scores was 1 to 16 out of a possible 20. The direct supply of sediment transport usually originates from the streambed and bank (Richards, 1982). All sites show at least moderate bank erosion; therefore, a large source of silt and sediment could be autochthonous (originating from within the stream), stressing the importance of bank stability. However, since erosion of watershed soils is ultimately the original source of sediment, surrounding land use most likely plays a role in the dominant contribution of allochthonous (originating from outside the stream) sources of sediment loading. Row crop agriculture and pastured land, the predominant land uses throughout the watershed, are typical sources of sediment and sediment-attached pollutants.

Channel alterations such as ditching, dredging, straightening, and other modifications also affect stream habitat diversity. Altering the natural stream morphology (shape) impacts riffle and pool development, resulting in less diverse habitat for macroinvertebrate and fish colonization. Temperature, dissolved oxygen concentrations, and suspended sediment and sediment-attached pollutant loads are some water chemistry parameters that are influenced by variations in channel morphology. Most of the stream sites have not been channelized recently, and if channelization occurred, appear to have recovered or be recovering from channelization. Other riparian zone alterations, such as canopy removal, have significantly degraded the stream reaches. As reflected in the QHEI evaluations, most of the sites studied show negative habitat impacts according to the respective channel morphology scores. Canopy removal often corresponds with vegetative buffer strip removal, which morphologically makes the channel more susceptible to bank erosion. Most of the Little Blue River Watershed sites possessed low sinuosity, which implies a lack of erosional and depositional zones, thereby decreasing the predictable pool-riffle sequencing found in healthy stream systems. Steep streambanks and straight reaches at most of the sites are indicators that these streams have been heavily modified and lack the natural sinuosity and development.

Typically in watersheds that are dominated by agricultural activity, stream channel morphology is greatly manipulated, jeopardizing the integrity of the biological communities. Pool development and quality is determined by the sorting of particles in that stream reach. Pools provide deeper areas with slower velocity for various macroinvertebrates, diversifying habitat. The lack of deep pool development is likely associated with land use alterations and the activity of increased erosion and siltation of the streambed, which then interferes with typical sorting of particles that form both riffles and pools (Allan, 1995). This scenario explains why typical riffle-pool patterns are lacking, but does not make a strong correlation within the watershed between the morphological characteristics and biological integrity.

Another important aspect of good habitat quality that is conspicuously missing from many of the study sites is an effective riparian zone to buffer stream systems from the surrounding land use. Stable, woody vegetation zones that naturally form adjacent to streams and other waterways provide distinct functions that enhance habitat quality (Ohio EPA, 1999). Primarily, this zone slows run off, collects sediment, and stores nutrients and sediment that would otherwise be loaded into the stream system. Poor QHEI and mIBI scores are also probably related to riparian zone absence. Extensive woody vegetation around streams provides additional habitat in the form of logs and woody debris, overhanging vegetation, and submerged root wads. Riparian vegetation also provides canopy cover that shades the stream and minimizes thermal inputs. Shade can also limit extensive, nuisance levels of aquatic vegetation that are dependent upon sufficient levels of solar radiation. Unfiltered nutrient-rich runoff can also promote vegetation and algal growth. Mowed grassy vegetation adjacent to streams does little to slow runoff flows into the stream, and therefore, is less capable of trapping sediments and nutrients. Based on observations made during sampling events, the quality and quantity of riparian zones are moderately to severely limited throughout the watershed.

Each of these physical factors contributes to habitat quality, and their absence or degradation at most of the sites is related to the macroinvertebrate community structure. Overall, the mIBI scores indicated slight to moderate impairment; the Middle Little Blue River, Upper Little Blue

River, and Farmers Stream sites possessed the highest quality macroinvertebrate communities. The Upper Little Blue River site received the second highest QHEI and mIBI scores suggesting that habitat factors do have an impact on the quality of ecological communities. In a healthy stream system, a community of both tolerant and intolerant taxa is expected. Impacts of degradation will tend to limit or eliminate organisms that are incapable of persisting in such systems. In general, tolerant taxa dominated the macroinvertebrate communities at Manilla Branch, the Upper Little Blue River, Little Gilson Creek, and the Little Blue River Headwaters leading to lower mIBI scores.

It is important to remember that overall watershed condition will impact habitat and biotic quality. In fact, scientific data suggest that watershed condition may have a greater influence on macroinvertebrate community measures than local riparian land use (Weigel et al., 2000). So although local streamside best management practices are important, a broader, watershed-level approach is necessary to effectively address biotic integrity and stream health. An additional study by Osmond and Gale (1995) showed that large-scale reductions in agricultural non-point source pollution are necessary for stream health improvement. An example of working at the watershed level includes coordinating with producers to implement nutrient, pesticide, tillage, and coordinated resource management plans.

6.3.7 Macroinvertebrate and Habitat Summary

Because many of the stream reaches surveyed had been channelized in the past, many natural stream characteristics are absent or severely deficient as indicated by the low QHEI scores. The habitat components most responsible for the aquatic life impairment within the Little Blue River Watershed streams include:

- Poor pool-riffle development: Deep places (pools) and shallow places (riffles) within a stream reach offer habitat variety for aquatic organisms and can impact certain chemical characteristics of flowing water like temperature, dissolved oxygen concentrations, and suspended sediment load. Pool-riffle development was poor at most study sites.
- Siltation/substrate embeddedness: Excessive loading of fine sediments and silt clogs or embeds the substrate spaces destroying habitat for aquatic macroinvertebrates and fish. Siltation and substrate embeddedness was high at most study sites.
- Channel alterations: Ditching, dredging, straightening, and other changes to channel structure can affect the ability of organisms to live in streams. Many study sites have been channelized in the past.
- Poor instream cover: Instream cover like undercut banks, overhanging vegetation, woody debris, and aquatic vegetation offer protection and habitat for aquatic organisms. Like pools and riffles, instream cover can also affect certain chemical characteristics like temperature and dissolved oxygen. Many study sites lacked instream cover.
- Lack of or very narrow riparian zones: Farming and other land use practices very near or even at the stream's edge decrease canopy cover over the stream increasing the thermal pollution in the stream and decrease the potential for woody debris (cover) in the stream. Additionally, narrow riparian areas do not filter or infiltrate runoff as efficiently as filter areas that are at least 30 feet (9.1 meters) wide (NRCS, 2000). Many study sites possessed narrow riparian zones.

The habitat characteristics evaluated as part of this study are important for the aquatic life in the streams. As one would expect, the impaired habitat conditions in the study streams were reflected in mIBI scores. In general, sites with poorer habitat fostered poorer macroinvertebrate communities. These communities typically exhibited a higher tolerance to pollution and lower diversity. All QHEI scores, except at Manilla Branch (Site 3), Beaver Meadow Creek (Site 6), and the Upper Little Blue River (Site 8), fell below 60. All sites except Farmers Stream (Site 7) and the Middle Little Blue River (Site 5) possessed impaired biotic communities.

Relationships among Chemical, Biological, and Habitat Characteristics
Chemical parameters and biological and habitat indices were analyzed for relationships that could provide additional insight into mechanisms governing impairment within the subwatersheds. The following list includes parameters for which no statistically significant linear relationship was found:

- QHEI score vs. HBI
- QHEI score vs. TSS (mg/l)
- QHEI score vs. Flow (cfs)
- QHEI score vs. Turbidity (NTU)
- QHEI score vs. mIBI
- mIBI vs. Ammonia-nitrogen (mg/l)
- mIBI vs. Soluble reactive phosphorus (mg/l)
- mIBI vs. Total phosphorus (mg/l)
- mIBI vs. Total suspended solids (mg/l)
- mIBI vs. Dissolved oxygen (mg/l)
- mIBI vs. Total Kjeldahl nitrogen (mg/l)
- QHEI Substrate vs. mIBI
- QHEI Cover vs. mIBI
- QHEI Riparian vs. mIBI
- QHEI Pool vs. mIBI
- QHEI Substrate vs. Turbidity (NTU)
- QHEI Substrate vs. Total suspended solids (mg/l)

One explanation for the overall lack of correlations is that these streams are, in general, moderately to highly modified and might not reflect natural relationships among parameters of water quality, habitat condition, and biological health. In many cases, the response variable shows limited ranges due to the streams modification, therefore a correlation is unlikely.

Three positive correlations were found among physical, chemical, and habitat parameters:

- QHEI score vs. mIBI
- mIBI vs. Flow (cfs)
- mIBI vs. Nitrate-nitrogen (mg/l)

While the QHEI was designed to evaluate stream habitat for fish communities, many of the metrics are also relevant for evaluating macroinvertebrate communities. Thus, one would expect a positive correlation between QHEI and mIBI scores. Essentially, habitat integrity should match the community composition. A positive, statistically significant relationship exists between these two parameters in the Little Blue River Watershed data (Figure 82). Generally, better (higher) QHEI scores support macroinvertebrate communities that possess greater taxa richness, higher numbers of individuals from pollution intolerant families, and greater EPT taxa density and diversity. It is important to note that the R^2 values for this relationship is approximately 0.5 suggesting that habitat scores explain half of the variability seen in the mIBI scores. This is to be expected since water quality likely affects the variability of the mIBI scores as well.

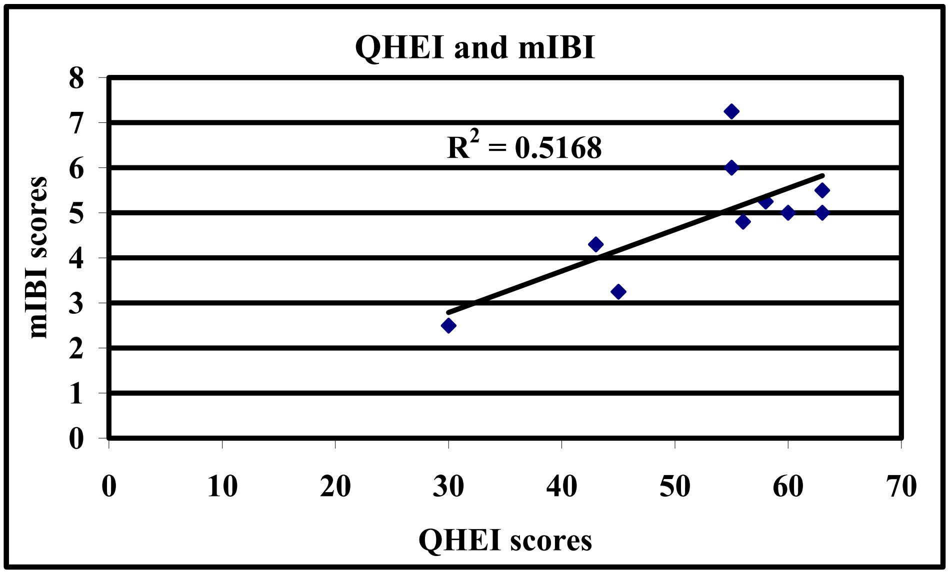


Figure 82. Statistically significant relationship ($p<0.01$) between QHEI scores and mIBI scores measured for the Little Blue River Watershed streams.

The relationship illustrated between discharge and mIBI (Figure 83) is expected based on the importance of flow and stream dynamics. Flowing water brings a continuous supply of nutrients and food particles to stream biota, not to mention increased dissolved oxygen. For example, the concentrations of dissolved organic matter (DOM) increase as a function of discharge in many streams (Allan, 1995). The concentration of particulate organic matter (POM) increases with the first flush of a storm event and then becomes diluted with additional discharge as the supply of POM is exhausted. In systems like the tributaries to the Little Blue River, where there is an overabundance of organic matter present in the stream and its substrate, higher discharges can mobilize and transport the POM. As Hynes (1970) stated in his classic work, current makes the water "physiologically richer" because of its constant renewal of materials in solution near the surfaces of stream organisms.

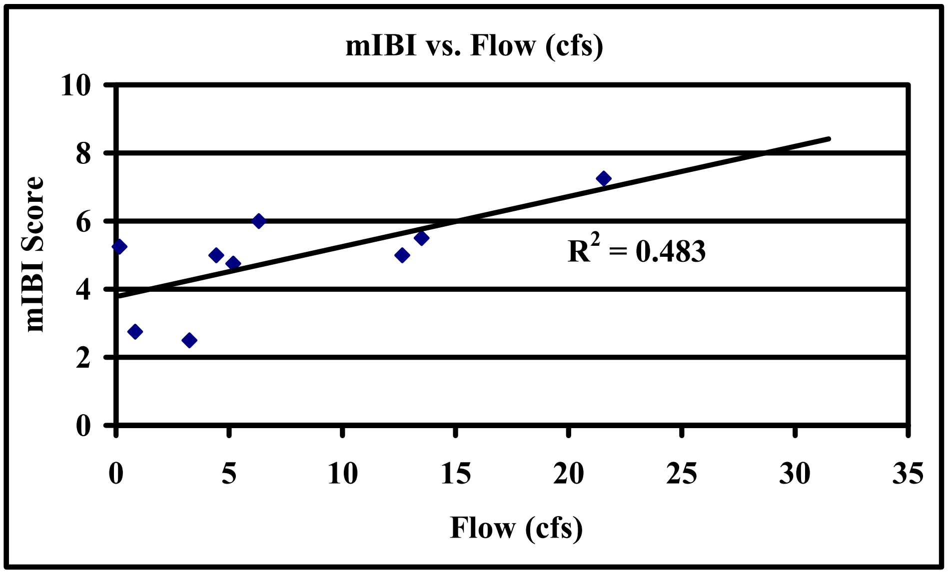


Figure 83. Statistically significant relationship ($p<0.01$) between discharge and mIBI measured for the Little Blue River Watershed streams.

The Ohio EPA found that degradation of the biotic community was observable when steams' median nitrate-nitrogen concentrations exceeded 3-4 mg/l (Ohio EPA, 1999). Low-flow nutrient data are usually used since low-flow conditions represent residual nutrient concentrations (Ohio EPA 1999). The low-flow nitrate concentrations of all of the study streams, except the Headwaters (Site 10), exceeded 3 mg/l. Figure 84 shows the statistically significant relationship between mIBI scores and nitrate-nitrogen concentration. Higher nitrate concentrations fostered insect communities of higher tolerance and lower diversity, resulting in lower mIBI scores.

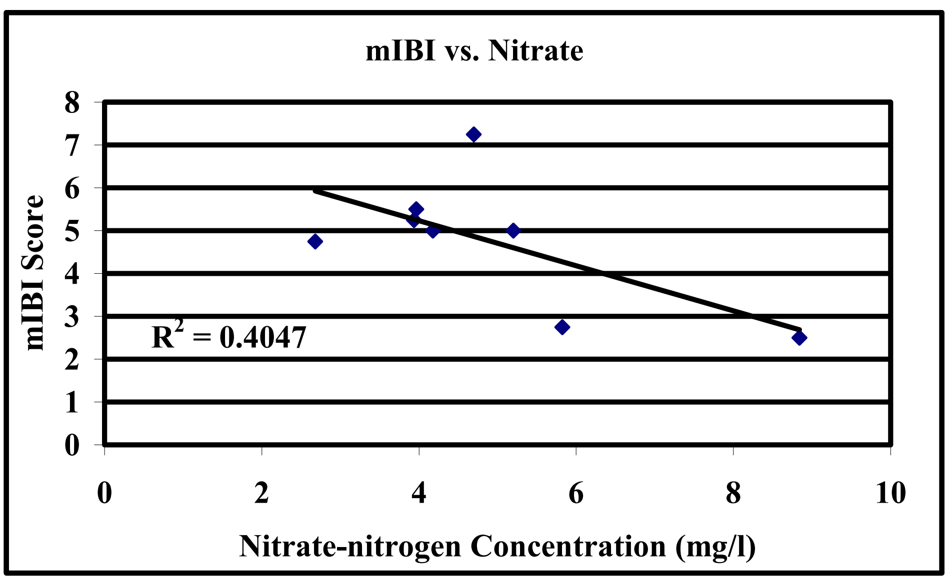


Figure 84. Statistically significant relationship ($p<0.05$) between nitrate-nitrogen concentration and mIBI scores measured in the Little Blue River Watershed streams.

Total phosphorus and soluble reactive phosphorus concentrations were not statistically related to macroinvertebrate community integrity within the Little Blue River Watershed. The Ohio EPA documented an inverse relationship between phosphorus concentrations and biological community performance in numerous streams in Ohio (Ohio EPA 1999). Excessive soil erosion and particulate and dissolved nutrient inputs have been shown to be associated with agricultural land use and stream degradation (Allan, 1995). Unlike their well-organized, diverse, and trophically dynamic high quality aquatic counterparts, degraded aquatic systems do not sequester available nutrients. Even though higher nutrient inputs are present within the watershed, there was no significant correlation with biological and habitat integrity.

Correlation with Historical Water Quality Data

Historical data that documented water chemistry, macroinvertebrate community structure, and habitat availability throughout the Little Blue River Watershed was discussed in the Historical Geochemical Studies and Biology of the Watershed Sections of this report. Very little of the data collected throughout the watershed corresponds with current sampling sites; therefore, it is difficult to draw direct comparison between historical data and data collected during the current study.

Historically, water quality samples collected throughout the watershed have documented elevated sediment, nutrient, and bacteria concentrations. Hoosier Riverwatch volunteers documented elevated nitrate-nitrogen, turbidity, and fecal coliform concentrations at the Lower Little Blue River (Site 1). During the current study, the Lower Little Blue River exhibited elevated nitrate-nitrogen and bacteria concentrations. Likewise, water quality data collected by IDEM in 1997 from the Little Blue River at German Road documented elevated total suspended solids, nitrate-nitrogen, turbidity, and *E. coli* concentrations on some sampling dates. (The German Road site is located approximately 2.0 river miles upstream of the Lower Little Blue River (Site 1).) *E. coli* levels in the Little Blue River watershed have historically been high. This is especially true for agricultural tiles, which are used to drain wet farmland. Historical data collected by the Rush County Health Department documented *E. coli* concentrations in drainage tiles as high as 8.7 million colonies per 100 ml (Table 27). More recent data collected by IDEM in 2002 from multiple locations within the Little Blue River Watershed show elevated *E. coli* concentrations (Table 28), which resulted in the Little Blue River Watershed being included on the 303(d) list of impaired waterbodies for *E. coli*. These historical data are consistent with data collected during this study where nearly all samples violated the Indiana *E. coli* standard.

The IDNR Division of Fish and Wildlife rated habitat using the QHEI at four reaches along the Little Blue River mainstem in 1995. These four reaches were spaced along the river from immediately downstream of the Lower Little Blue River (Site 1) northeast toward the Middle Little Blue River (Site 5). All reaches received higher QHEI scores (67 to 69) than any of the sites scored during this study. However, all of these sites were located at sites accessed via a fish-shocking boat and were located away from bridge crossings. Most reaches possessed high quality riparian areas dominated by large trees and shrubs. Additionally, channel alterations and substrate degradation often associated with artificial substrate additions near bridges were not present at the sites surveyed by the IDNR. Both of the stream reaches assessed in this portion of the watershed, the Lower Little Blue River (Site 1) and the Middle Little Blue River (Site 5), during the current study suffer from riparian buffer and/or channel alterations, thereby creating poorer habitat quality than those assessed by the IDNR in 1995.

IDEM surveyed the two major branches of Beaver Meadow Creek upstream of State Road 52 in 1993. The two sites surveyed by IDEM were located in the upper portions of the subwatershed where the streams are heavily impacted by anthropogenic alterations. QHEI scores at both sites were lower (52 to 55) than the score during the current survey of Beaver Meadow Creek (60). Reduced riffle-pool development, poor substrate quality, and lack of riparian habitat limited habitat availability at the two upper watershed sites during the historic survey. The macroinvertebrate community was dominated by pollution tolerant taxa resulting in lower mIBI scores (3.8 to 4.0) at these sites than that observed further downstream during the current survey (5.0).

6.4 WATER QUALITY ASSESSMENT SUMMARY

High nitrate-nitrogen concentrations and *E. coli* concentrations that exceeded the state standard were the water chemistry issues of most concern in Little Blue River Watershed streams. All of the Little Blue River tributaries possessed nitrate-nitrogen concentrations greater than the state standard (10 mg/l) during storm flow. During base flow, the Little Blue River mainstem sites contained nitrate-nitrogen concentrations that exceeded the median level known to support warmwater biota; tributary concentrations exceeded the median level known to support modified warmwater biota in Ohio streams (Ohio EPA, 1999). Concentrations throughout the watershed are within or above the range shown by the Ohio EPA to impair aquatic biotic integrity. Likewise, nitrate-nitrogen concentrations exceed the USEPA recommended nutrient criterion during both base and storm flow at all stream sites. Fertilizers and animal wastes (human, wildlife, and livestock) are the most common sources of nitrate-nitrogen in streams.

E. coli concentrations exceeded the Indiana state standard (235 colonies/100 ml) at the Lower (Site 1) and Middle Little Blue River (Site 5), Manilla Branch (Site 3), and Farmers Stream (Site 7) during base flow and at all sites during storm flow. At sites where elevated concentrations were observed, concentrations were 1.2 to 76 times the state standard. Additionally, bacteria levels were high when compared with other agricultural watersheds in Indiana. The sources of *E. coli* in the Little Blue River Watershed have not been identified; however, wildlife, livestock and/or domestic animal defecations; manure fertilizers; previously contaminated sediments; and failing or improperly sited septic systems are common sources of the bacteria. Many of these issues were documented historically and/or observed during the windshield tour at multiple sites throughout the watershed. Efforts to reduce nitrate-nitrogen and *E. coli* concentrations within the watershed streams should target cattle fencing, manure management planning, and septic system failure identification and subsequent improvements.

Four of the Little Blue River tributaries, Rays Crossing (Site 2), Cotton Run (Site 4), Little Gilson Creek (Site 9), and Manilla Branch (Site 3) generally possessed poorer water quality conditions than the other three tributaries. The Rays Crossing Tributary Subwatershed loaded more ammonia-nitrogen, total Kjeldahl nitrogen, total phosphorus, and total suspended solids per unit area during storm flow than any of the other subwatersheds. This subwatershed also contained the highest ammonia-nitrogen and soluble reactive phosphorus and second highest total Kjeldahl nitrogen, total phosphorus, and total suspended solids loads per unit area during base flow. Rays Crossing Tributary (Site 2) also possessed the highest ammonia-nitrogen concentrations during base and storm flow and the highest total phosphorus concentration during storm flow. The Rays Crossing Tributary (Site 2) QHEI score indicates that habitat is poorer than the value (60) observed to be conducive to supporting warmwater fauna in Ohio streams (Ohio EPA, 1999). The relatively poor water quality combined with habitat determined to be partially supporting for the stream aquatic life use designation contributes to the slightly impaired macroinvertebrate community observed in the stream. Low EPT taxa density and diversity, high taxa richness, and balanced diversity of pollution tolerant and intolerant taxa characterized the macroinvertebrate community at Rays Crossing Tributary.

Like Rays Crossing (Site 2), Cotton Run (Site 4) possessed poor water quality relative to the other watershed streams. The Cotton Run Subwatershed possessed the highest total phosphorus and total suspended solids loads per unit area of any of the subwatersheds. This indicates that on a regular basis more sediment and sediment-attached pollutants per unit area are entering Cotton Run (Site 4) than any of the other watershed streams under base flow conditions. Habitat within Cotton Run (Site 4) is limited by poor riffle-pool development, lack of instream and canopy cover, and poor channel development. Using IDEM's suggested criterion, Cotton Run's habitat does not support the stream's aquatic life use designation. Relatively poor water quality and poor habitat quality created conditions that are not conducive to supporting a diverse, pollution intolerant macroinvertebrate community in Cotton Run as reflected by its low mIBI score.

Although it generally has better water quality than most of the tributaries, Little Gilson Creek, exhibited the highest nitrate-nitrogen concentrations during both base and storm flow. It also possessed the poorest habitat observed at all of the watershed streams. Poor pool-riffle development, lack of instream and riparian cover, and poor substrate and channel stability characterize the Little Gilson Creek reach. A base flow nitrate-nitrogen concentration that exceeds by a factor of 2-3 the level found the Ohio EPA to impair biotic integrity and poor habitat quality created conditions that are not conducive to supporting a highly diverse, pollution intolerant macroinvertebrate community in Little Gilson Creek as reflected in its poor mIBI score.

The Manilla Branch (Site 3) also possessed poor water quality relative to the other watershed streams. Manilla Branch contained elevated dissolved nutrient concentrations during both base and storm flow. Elevated total phosphorus concentrations combined with low particulate phosphorus concentrations indicate that most of the phosphorus available in Manilla Branch is readily available, soluble phosphorus. Nitrate-nitrogen concentrations also exceeded median levels known to support warmwater fauna (Ohio EPA, 1999). Conversely, Manilla Branch possessed the highest habitat quality observed in the Little Blue River Watershed streams. Developed pools and riffles, high substrate variability and stability, and good channel morphology creates a spatially heterogeneous stream reach conducive to support warmwater fauna (Ohio EPA, 1999). However, high densities of pollution tolerant taxa and low numbers and diversity of pollution intolerant EPT taxa characterize the moderately impaired macroinvertebrate community within Manilla Branch. Given the relatively good habitat observed in the stream, it is likely that water quality is impairing the macroinvertebrate community within Manilla Branch.

The middle and upper portions of the Little Blue River possessed relatively good water quality compared to the lower portion of the Little Blue River as reflected by possessing two of the highest quality macroinvertebrate communities observed in the watershed streams. The Lower Little Blue River (Site 1) contained the greatest loads for all parameters during both base and storm flow. This is to be expected; since the site is located furthest downstream, it receives pollutants from all other sites. However, with the exception of soluble reactive phosphorus, the mainstem subwatersheds loaded the lowest volume of all parameters per unit area of all of the subwatersheds. Habitat at the Middle and Upper Little Blue River (Sites 5 and 8) sites was also relatively good. The Upper Little Blue River (Site 8) habitat was the highest quality habitat observed at all of the watershed streams and is characterized by relatively good pool and riffle development, high channel stability and morphology, and diverse instream habitat. Habitat quality within the Middle Little Blue River (Site 5) and Lower Little Blue River (Site 1) reaches is poorer than that observed at the Upper Little Blue River (Site 8) reach. The Lower Little Blue River (Site 1) contains the poorest habitat of the three sites; it is characterized by the lack of pools and riffle development, high levels of substrate embeddedness, and poor instream and riparian cover, which limit habitat availability. The macroinvertebrate communities observed in the middle and upper portions of the mainstem reflects the relatively good water quality and habitat at these sites. The Middle Little Blue River (Site 5) contained the highest quality macroinvertebrate community observed in any of the watershed sites. The non-impaired macroinvertebrate community observed at this site was characterized by high densities and diversities of pollution intolerant taxa, specifically members of the *Plecopteran* order, which are some of the most pollution intolerant taxa. The Upper Little Blue River's (Site 8) slightly impaired community also contained high densities and diversities of pollution intolerant taxa. Conversely, the macroinvertebrate community observed at the Lower Little Blue River (Site 1) was moderately impaired, likely due to both the relatively poor water quality and limited habitat availability at this site.

7.0 PHOSPHORUS MODELING

Since phosphorus is the limiting nutrient in most streams, watershed management programs often target phosphorus as a nutrient to control. Because of this, a phosphorus model was used to estimate the dynamics of this important nutrient in the Little Blue River Watershed. The limited scope of this LARE study did not allow us to determine phosphorus inputs and outputs outright. Therefore, a standard phosphorus model was used to estimate the phosphorus budget. Reckhow et al. (1980) compiled phosphorus loss rates from various land use activities as determined by a number of different studies, and calculated phosphorus export coefficients for each land use in the watershed. Mid-range estimates of these phosphorus export coefficient values were utilized for most watershed land uses (Table 64).

Table 64. Phosphorus export coefficients (units are kg/hectare except the septic category, which are kg/capita-yr).

Estimate Range	Row Crops	Non-Row	Pasture	Forest	Precipitation	Urban	Septic
High	5.0	1.5	2.5	0.3	0.6	3.0	1.8
Mid	2.0	0.8	0.9	0.2	0.3	1.0	0.4-0.9
Low	1.0	0.5	0.1	0.1	0.15	0.5	0.3

Source: Reckhow et al., 1980.

Phosphorus export coefficients are expressed as kilograms of phosphorus lost per hectare of land per year. These are multiplied by the amounts of land in each of the land use category to derive an estimate of annual phosphorus export (as kg/year) for each land use per watershed (Table 65).

Because agriculture is the dominant land use within each of the tributary subwatershed units, the proportional mass of phosphorus estimated from agricultural land is also high, nearly 97% of the total estimated phosphorus loss. The percentage of phosphorus loss due to row crops ranged from 88.7% in the Rays Crossing Tributary Subwatershed to a high of 95.8% in the Little Gilson Creek Subwatershed. When the data was normalized for tributary subwatershed area (Table 66), all subwatersheds contributed similar amounts of phosphorus. According to the model, the Little Gilson Creek Subwatershed loaded the most phosphorus per unit area (1.88 kg P/ha-yr). The model estimates that 26,379 kilograms (29.1 tons) of phosphorus is lost from lands draining through the tributary within the watershed each year.

To better understand the spatial differences in watershed phosphorus export, the watershed was divided into three approximately equal segments which correspond with the Lower, Middle, and Upper Little Blue River Subwatersheds. The distribution of land use and predicted phosphorus export from these three areas were approximately equal. The Upper Little Blue River Subwatershed contributed the most phosphorus (17,142 kg P/yr; Table 67) while the Middle Little Blue River Subwatershed contributed the lowest amount of phosphorus (14,563 kg P/yr). When the data was normalized for mainstem subwatershed area (Table 66), the three subwatersheds contributed similar amounts of phosphorus. According to the model, the Lower Little Blue River Subwatershed loaded the least phosphorus per unit area (1.67 kg P/ha-yr), while the Upper Little Blue River Subwatershed loaded most phosphorus per unit area (1.80 kg P/ha-yr). The model estimates that 47,553 kilograms (52.4 tons) of phosphorus is lost from lands within the project area each year. Significant reduction of phosphorus loading to local streams will necessitate additional management of agricultural sources.

Table 65. Results of phosphorus export modeling by tributary subwatershed given in kilograms per year.

	P Export Coefficient (kg/ha-yr)[a]	Rays Crossing (2)[b]	Manilla Branch (3)	Cotton Run (4)	Beaver Meadow Creek (6)	Farmers Stream (7)	Little Gilson Creek (9)	Headwaters (10)	TOTALS	% of Total
Deciduous Forest	0.2	15.3	10.6	6.2	11.3	2.6	2.9	13.7	62.6	0.24%
Emergent Herbaceous Wetlands	0.1	--	--	--	0.2	--	0.5	0.4	1.0	0.00%
High Intensity Residential	1.9	0.3	0.8	--	1.3	--	--	3.5	5.9	0.02%
High Intensity Commercial	1.5	3.2	1.1	--	1.8	--	--	7.9	14.0	0.05%
Low Intensity Residential	1.0	1.1	17.9	--	7.1	--	--	2.5	28.5	0.11%
Urban Parkland	1.0	--	--	--	3.8	--	--	--	3.8	0.01%
Agriculture Pasture	0.9	169.0	147.4	98.5	740.5	96.4	96.0	518.8	1,866.5	7.08%
Row Crops	2.0	1,483.0	1,891.5	1,504.8	8,386.5	1,383.9	2,306.9	7,439.6	24,396.3	92.48%
Woody Wetlands	0.1	0.3	0.2	--	0.8	--	0.2	2.2	3.7	0.01%
TOTAL	**--**	**1,671.9**	**2,069.3**	**1,609.5**	**9,152.5**	**1,482.8**	**2,406.1**	**7,986.4**	**26,378.6**	**100%**

[a]From Reckhow et al., 1980.; [b]All units are kilograms phosphorus per year.

Table 66. Results of phosphorus export modeling by tributary (☐) and mainstem (■) subwatershed given in kilograms per hectare per year.

Subwatershed	Phosphorus Export (kg/ha-yr)
Lower Little Blue River (1)	1.67
Rays Crossing Tributary (2)	1.65
Manilla Branch (3)	1.75
Cotton Run (4)	1.80
Middle Little Blue River (5)	1.75
Beaver Meadow Creek (6)	1.79
Farmers Stream (7)	1.83
Upper Little Blue River (8)	1.80
Little Gilson Creek (9)	1.88
Headwaters (10)	1.82

Table 67. Results of phosphorus export modeling by mainstem subwatershed given in kilograms per year.

	P Export Coefficient (kg/ha-yr)[a]	Lower Little Blue River (1) [b]	Middle Little Blue River (5)	Upper Little Blue River (8)	TOTALS	% of Total
Deciduous Forest	0.2	127.2	48.4	44.0	219.6	0.46%
Emergent Herbaceous Wetlands	0.1	0.1	0.2	1.8	2.1	0.00%
High Intensity Residential	1.9	64.4	2.1	3.5	70.1	0.15%
High Intensity Commercial	1.5	186.6	9.4	7.9	204.0	0.43%
Low Intensity Residential	1.0	100.3	32.3	3.9	136.6	0.29%
Urban Parkland	1.0	27.6	33.1	0.0	60.7	0.13%
Agriculture Pasture	0.9	1,398.4	1,190.6	1,068.5	3,657.5	7.69%
Row Crops	2.0	13,937.3	13,242.9	16,006.9	43,187.2	90.82%
Woody Wetlands	0.1	5.2	4.1	5.7	15.0	0.03%
TOTAL	**--**	**15,847.4**	**14,563.3**	**17,142.2**	**47,552.8**	**100%**

[a]From Reckhow et al., 1980.; [b]All units are kilograms phosphorus per year.

8.0 MANAGEMENT OPTIONS

Before any management actions are taken, a comprehensive plan that considers the current and best uses of the Little Blue River and its tributaries and includes input from streamside homeowners, watershed homeowners, and stream users alike must be carefully crafted. Critical to this evaluation is a consideration of the 'nature' of the stream and its tributaries themselves.

Regardless of the water quality goals that watershed stakeholders ultimately set, there are many watershed management and near stream techniques available to address the characteristics of concern listed in the previous sections of this report. The following sections describe many of the techniques most applicable to the waterbodies of the Little Blue River Watershed. For the sake of clarity, the techniques are separated into two categories: watershed management techniques and near stream management techniques.

8.1 WATERSHED MANAGEMENT

Nearly 95% of the Little Blue River Watershed is utilized for agricultural production or pastureland. According to the phosphorus model, agricultural land contributes 46,845 kg/yr of phosphorus. As the predominant land use, most of the watershed management techniques focus on agricultural Best Management Practices (BMPs). Only a small percentage of the watershed, approximately 1.5%, contains residential or commercial development; however, the City of Shelbyville is undergoing rapid development and would benefit from planned growth, stormwater management, and zoning ordinances. Additionally, smaller urban areas including Manilla, Rays Crossing, Arlington, and Mays are continuing to increase in size and population. Therefore, urban and individual homeowner best management practices are also included.

8.1.1 Agricultural Best Management Practices (BMPs)

Approximately 80% of the Little Blue River Watershed is utilized for agricultural row crop production. This land use, particularly on highly erodible soils and in other environmentally sensitive areas, can have an impact on water quality downstream. Runoff from farm fields can contain a variety of pollutants including nutrients (nitrogen and phosphorus), herbicides, pesticides, sediment, and bacteria (*E. coli*). According to the National Research Council (1993), non-point source pollution by contaminants in agricultural runoff is a major cause of poor surface water quality in the United States. In addition, the development of land for agricultural purposes involved draining low wet areas using tiles and ditches. This has decreased the storage capacity of the land and increased peak flows in streams and channels in the watersheds. An increase in both the volume and velocity of peak flows typically leads to increases in streambed and bank erosion and ultimately increases in sediment and sediment-associated particle loading to the receiving waterbody.

Several programs and Best Management Practices (BMPs) have been developed to address non-point source pollution associated with agriculture. BMPs may be structural or managerial in nature (Osmond et al., 1995). Filter strips, riparian buffer strips, grassed waterways, and use of other erosion control structures are examples of structural practices, while rotational grazing, conservation tillage, and nutrient and pesticide management are managerial BMPs. Each BMP helps ensure healthy and productive farmland while protecting sensitive areas on the landscape.

Programs and BMPs that are currently in use in the study watershed or that could potentially be used more frequently or consistently are discussed below.

The Conservation Reserve Program

The Conservation Reserve Program (CRP) is the single, largest environmental improvement program offered by the federal government. The program arose out of concerns raised through USDA studies conducted in the early 1980s showing that the nation's cropland was eroding and losing soil at a rate of 3 billion tons per year (USDA, 1997). The CRP provides volunteer participants with an annual per-acre rent and a lump sum payment equal to 50% of the cost of establishing permanent land cover. In return, participants are required to retire the cropland from production for 10-15 years.

Removing land from production and planting it with vegetation has a positive impact on water quality within the given watershed. In a review of Indiana lakes sampled from 1989 to 1993 for the Indiana Clean Lakes Program, Jones (1996) showed that lakes within ecoregions reporting higher percentages of cropland in CRP had lower mean trophic state index (TSI) scores. A lower TSI is indicative of lower productivity and better water quality.

The Conservation Reserve Program is targeted at the most environmentally sensitive land into the program. In the 2002 Farm Bill, Congress capped the program at 39.2 million acres, meaning that only about 15% of eligible cropland could be enrolled. Land is evaluated and scored for environmental benefit, including: wildlife habitat enhancement, water quality benefits, reduced erosion, long-term retention benefits, air quality benefits, land's location in a Conservation Priority Area, and cost of enrollment per acre. The CRP attempts to maximize conservation and economic benefits by focusing on highly erodible land, riparian areas, cropped wetlands, and cropland that contains wetlands that are not farmed. The Manilla Branch, Rays Crossing Tributary, and Beaver Meadow Creek Subwatersheds contain the highest HEL:CRP ratios and would benefit from landowner enrollment in the Conservation Reserve Program.

Conventional Structural Conservation Practices

Continuous sign-up is permitted through the CRP for special high-priority conservation practices that lead to significant environmental benefits. These practices are structural in nature and are specially designed to protect and enhance wildlife habitat, improve air quality, and improve waterway condition. These conservation practices and relevant research involving their use are discussed in more detail below.

Filter Strips

A filter strip is an area of grass or other permanent vegetation used to reduce sediment, organic material, nutrients, pesticides, and other contaminants in runoff. Filter strips slow the velocity of water, allowing settling of suspended particles, infiltration of runoff, adsorption of pollutants on soil and plant surfaces, and uptake of soluble pollutants by plants. Slower runoff velocities and reduced flow volumes lead to decreased downstream erosion.

A modeling study by Texas A&M University suggests that if filters were properly installed in all appropriate locations, sediment delivery to rivers and lakes could be reduced by two-thirds (National Conservation Buffer Council, 1999). Preventing sediment delivery to streams has important and significant economic ramifications. According to a study by the Ohio State University Extension Service, a 25% decrease in the amount of sediment entering waterways in the state would save $2,700,000 in water treatment costs per year (Leeds et al., 1997). The cost of dredging sediment out of these waterways was estimated at $1,500,000 per year for the state of Ohio. Additionally, buffer strips have been associated with healthier aquatic communities (Wiegel et al., 2000).

Typically, filter strips are planted on cropland at the lower edge of a field or adjacent to waterways. They are most effective when receiving shallow, uniform flow rather than concentrated runoff localized in channels or gullies. The Natural Resources Conservation Service (NRCS) recommends minimum filter strip widths be based on intended purpose of the area (NRCS, 2000). The minimum length across which water should flow prior to entering the waterbody is set at 20 ft (6 m), but the minimum can be increased to 30 ft (9 m) based on sediment, particulate organic matter, and sediment-adsorbed contaminant loads in runoff. The average watershed slope above the filter strip must be greater than 0.5% but less than 10%. The NRCS standard is site-specific with plans and specifications required for each field site where a filter strip will be installed. It is important to keep in mind that effective filter strip width is also dependent on the amount of land draining into the filter. Ratios of the field drainage area to the filter area should be no greater than 50:1. Based on a survey of more than 2,700 CRP sites in the United States, the ratio averaged approximately 3:1 (Leeds et al., 1993).

A wide variety of vegetation types have been used for planting filter strips. The ideal plant or combination of plants would possess the following characteristics: native to Indiana; sod-forming; palatable as forage; somewhat cool season so as to grow early in spring when most runoff events occur; hardy, rapidly growing, and tolerant of nutrient-poor conditions so as to not need fertilization; able to remain standing throughout the winter providing shelter for wildlife; and economical/affordable.

The use of plants native to Indiana is ecologically the most desirable alternative. (Please see the NRCS Conservation Practice Standard Code 393 for specifics and requirements regarding vegetation planting within filter strips (NRCS, 2000).) Advantages of planting native vegetation are that: 1) native species possess extensive rooting structures that hold soil and reduce erosion (Figure 85 depicts rooting depths of several native grass species); 2) many native species can be hayed for forage use, and in fact big bluestem and Indian grass are highly palatable for forage (Clubine, 1995); 3) native species are hardy and able to withstand various hydrologic regimes; 4) native species have low maintenance requirements and cost less over the long-run due to natural re-seeding processes and hardiness; 5) native species possess lower nutrient requirements and therefore do not require costly fertilization which can further impair water quality; 6) native plants provide wildlife habitat by remaining standing through the winter; 7) native wildflowers are beautiful, and their seeds can be added to mixes for aesthetic value; and 8) some legume species like roundhead lespedeza, prairie clover, lead plant, and tickclover are quite resilient to livestock grazing (Clubine, 1995).

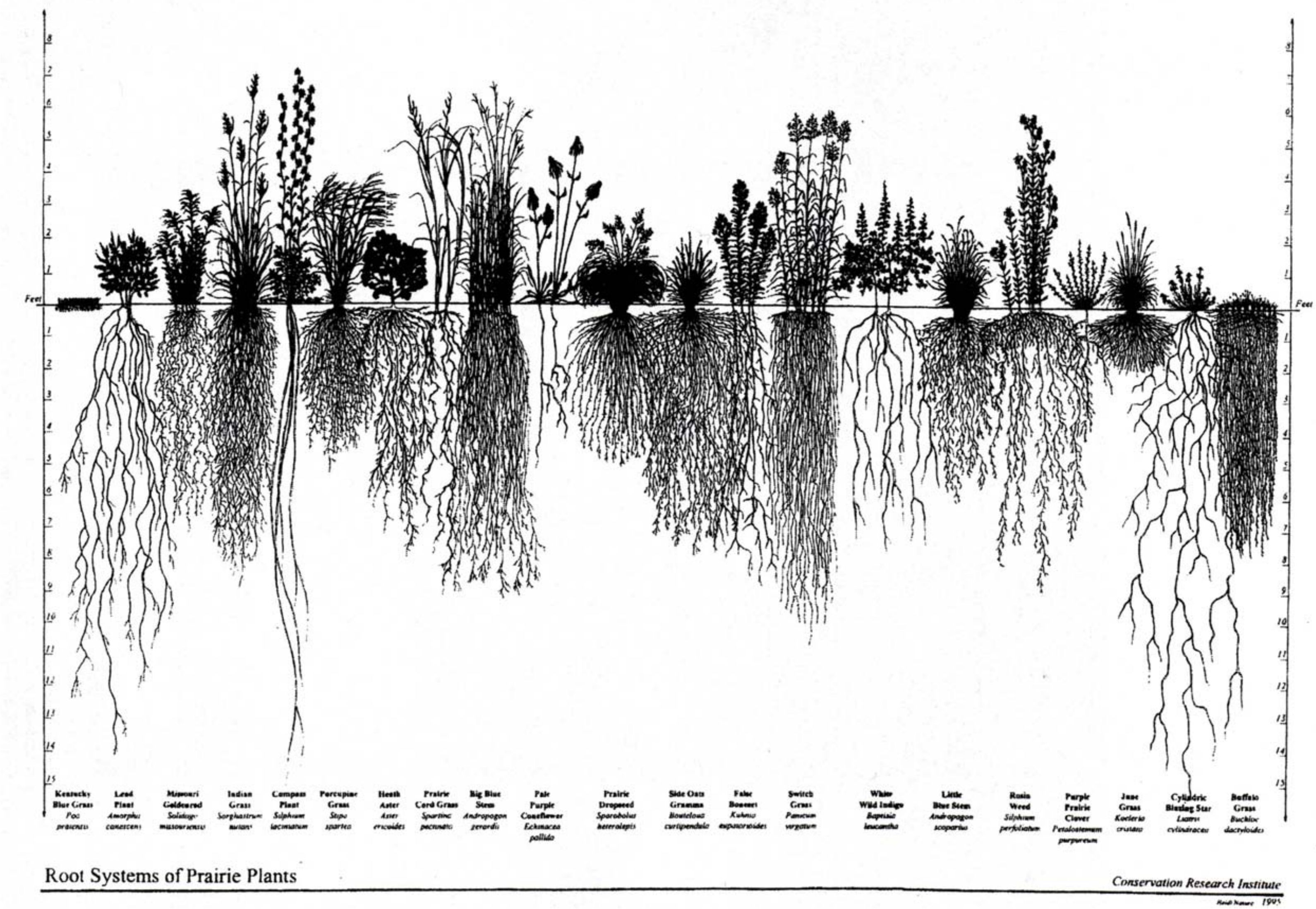


Figure 85. Rooting depths of native grasses and forbs.

Some disadvantages of establishing native herbaceous vegetation in filter strips also exist because: 1) most native grasses are warm season (except for red top and Virginia wildrye) and may not offer optimal nutrient uptake in early spring when many runoff events occur; 2) some species have been reported to be difficult to establish and may take years for full stand development (Leeds et al., 1993); 3) native wildflower plants and other forbs can be quite susceptible to herbicides used in crop production; 4) many native species are quite expensive to produce (see tables in Appendix I); and 5) some native legume species like Illinois bundleflower have been shown to be susceptible to grazing (Clubine, 1995).

Appendix I contains lists of recommended native cool season grasses, legumes, and wildflowers. Information is also presented on species that are considered less than desirable as filter strip vegetation. Five different recommended mixes are provided along with seeding rates in lbs/acre and approximate costs according to the February of 2001 price listing of Sharp Bros. Seed Company of Missouri and the J.F. New Native Plant Nursery 2001 Wholesale Catalog. 2001 prices are listed to provide an idea of the cost associated with these seed mixes. Seed prices may have changed since 2001; therefore, these and other seed companies should be consulted prior to seed purchase. Mixes should be chosen based on the landowner's specific application and available finances. Table 68 lists vegetation types that should not be used due to severe limitations. It is important to remember that a filter strip or conservation easement planted with any vegetation type is better than not having the easement at all. Even if optimal mixes are not chosen or utilized, an individual's participation in a set-aside program will have positive effects for water quality.

Table 68. Plant species that are generally not good candidates for use in filter strips and reasons for their unsuitability. The reasons listed in the table represent the opinions of JFNew and are based on scientific literature, experience and observation, and rooting physiology information.

Species	Reasons for Unsuitability
Birdsfoot trefoil	poor rooting structure with little ability to stabilize soil
Smooth brome	poor rooting structure with little ability to stabilize soil
Fescue	poor rooting structure with little ability to stabilize soil
Japanese millet	poor rooting structure with little ability to stabilize soil
Orchardgrass	poor rooting structure with little ability to stabilize soil
Reed canarygrass	poor rooting structure with little ability to stabilize soil; invasive; excludes other more beneficial vegetation; no wildlife habitat benefit
Crownvetch	poor rooting structure with little ability to stabilize soil; invasive
Kentucky bluegrass	very shallow root system; invasive; excludes other more beneficial vegetation; no wildlife habitat benefits
Perennial rye	invasive; excludes other more beneficial vegetation
Red clover	poor rooting structure with little ability to stabilize soil; somewhat weedy and invasive
White clover	poor rooting structure with little ability to stabilize soil; somewhat weedy and invasive

It is also necessary here to caution landowners who receive federal and/or state monies for planting vegetation. Certain programs may require special seeding mixtures. For example, CRP filter strips must be planted as per Tables 1 and 2 in the NRCS Conservation Practice Standard Code 393 (NRCS, 2000). The eight tables included in Appendix I give recommendations for landowners who may be purchasing their own seed or have received cost-share monies from programs that are more flexible with respect to seeding requirements.

Filter strip effectiveness has been the subject of voluminous recent research. Most research indicates that filter strips are effective at sediment removal from runoff with reductions ranging from 56-97% (Arora et al., 1996; Mickelson and Baker, 1993; Schmitt et al., 1999; Lee et al, 2000; Lee et al., 2003). Most of the reduction occurs within the first 15 feet (4.6 m). Smaller additional amounts are retained and infiltration is increased by increasing the width of the strip (Dillaha et al., 1989). Filter strips have been found to reduce sediment-bound nutrients like total phosphorus but to a lesser extent than they reduce sediment load itself. Phosphorus predominately associates with finer particles like silt and clay that remain suspended longer and are more likely to reach the strip's outfall (Hayes et al., 1984). Filter strips are least effective at reducing dissolved nutrient concentration like those of nitrate, dissolved phosphorus, atrazine, and alachlor, although reductions of dissolved phosphorus, atrazine, and alachlor up to 50% have been documented (Conservation Technology Information Center, 2000). Simpkins et al. (2003) demonstrated 20-93% nitrate-nitrogen removal in multispecies riparian buffers. Short groundwater flow paths, long residence times, and contact with fine-textured sediments favorably increased nitrate-nitrogen removal rates. Additionally, up to 60% of pathogens contained in runoff may be effectively removed. Computer modeling also indicates that over the long run (30 years), filter strips significantly reduce amounts of pollutants entering waterways.

Filter strip age is an additional factor of importance for effective function. Schmitt et al. (1999) found older grass plots (25 yr-old) to be more effective filters than recently planted ones (2 yr-old). A longer amount of time was required for runoff to reach the outfall of the older plots, suggesting that a strip's ability to slow runoff and filter pollutants increases with age.

Filter strips are effective in reducing sediment and nutrient runoff from feedlot or pasture areas as well. Olem and Flock (1990) report that buffer strips remove nearly 80% of the sediment, 84% of the nitrogen, and approximately 67% of the phosphorus from feedlot runoff. In addition, they found a 67% reduction in runoff volume. However, it is important to note that filter strips should be used as a component of an overall waste management system and not as a sole method of treatment.

Filter strips, like all conservation practices, require regular maintenance in order to remain effective. Maintenance consists of: 1) frequent inspection of the project filter strip after large storm events; 2) repairing and reseeding of any areas where erosion channels develop; 3) reseeding of bare areas; 4) mowing and removing hay to maintain moderate vegetation height. Filter strip vegetation should not be cut lower than 6 inches. To avoid destruction of wildlife nesting areas, delay mowing until after mid-July; 5) controlling trees, brush, and noxious or invasive weeds within the filter; and 6) applying fertilizer and lime at rates suggested by regular soil testing.

Many of the Little Blue River Subwatersheds could benefit from the creation of filter strips between row crop agricultural fields or livestock-grazed pastures and the adjacent stream. Filter strips are recommended at locations shown on Figure 30. Beaver Meadow Creek, the Headwaters, and the Lower Little Blue River Subwatersheds contain the highest number of locations where filter strips could be implemented. Priority should be given to these subwatersheds because of high total suspended solids and particulate phosphorus loads during both base and storm flow.

Riparian Buffers

In many ways similar to filter strips, riparian buffers are streamside plantings of trees, shrubs, and grasses intended to intercept pollutants before they reach a river or stream. Although comparisons reveal that riparian buffers are no better than grassed strips at retaining nutrients and sediment, they offer shade and cover to the stream, thereby providing valuable fish and wildlife habitat (Daniels and Gilliam, 1996). Due to their deeper rooting systems, riparian buffers can filter both surface and subsurface runoff before it reaches the waterway. The rooting systems of riparian buffers can also serve to stabilize banks and soils, especially along ditches that pass through mucky or easily erodible soil. Priority should be given to riparian buffer installation along portions of the Headwaters and Lower Little Blue River Subwatersheds, each of which contain notable acreages of areas where riparian vegetation had been removed. (The Urban Best Management Practices Section of this report contains riparian buffer information targeted at individual, urban landowners implementing riparian buffers.)

Field Borders

Field borders are 20-ft wide filter strips or bands of perennial vegetation planted at the edge of fields that can be used as turning areas for machinery. They also provide wildlife cover, protect water quality, and reduce sheet, rill, and gully erosion. Borders should be repaired and reseeded after storms and should be mown and harvested in late summer to early fall to encourage growth for the next spring. Many farm fields within the Little Blue River Watershed already utilize field borders; however, some fields in the Upper Little Blue River Subwatershed observed during the windshield tour could benefit from wider field borders.

Shelterbelts/Windbreaks

Shelterbelts are rows of trees, shrubs, or other vegetation used to reduce wind erosion and protect crops while also providing protection for wildlife, livestock, houses, and other buildings. Similar to shelterbelts, windbreaks or hedgerows are located along crop borders or within fields themselves. Air quality improvement and wildlife habitat provision are the greatest benefits of these vegetation belts. Locations where shelterbelt and/or windbreak installation could occur were not identified during either the aerial survey or the windshield tour. However, many areas in the Little Blue River Watershed could benefit from their installation. Specific installation locations will need to be identified during on the ground field tours.

Grassed Waterways

Grassed waterways are natural or constructed channels that are seeded with filter vegetation and shaped and graded to carry runoff at a non-erosive velocity to a stable outlet and vegetated filter. Vegetation in the waterway protects the topsoil from erosion and prevents gully formation, while providing cover for wildlife. The stable outlet is designed to slow and spread the flow of water and direct it towards the vegetated filter.

Grassed waterways are typically used where water tends to concentrate, like in draws, washouts, or other low-lying gully areas. They can also be used as outlets from other conservation practices (like terraces) or in any other situation where a stable outlet and vegetated filter can be built and maintained.

These vegetated systems may be trapezoidal or parabolic in shape, but should be broad and shallow in construction. They should be able to carry the runoff of a 10-year storm event. The stable outlet should be planted with perennial, sod-forming grasses to provide a dense area of vegetation to cause sediment and sediment-attached pollutant deposition. The vegetated area below the outlet should be constructed as a typical filter strip would be.

Proper operation and maintenance is necessary for effective grassed waterway function. Tillage and crop row direction should be perpendicular to the waterway to allow drainage and to prevent water movement along edges. Machinery crossing areas should be stabilized to prevent damage to the grassed waterway. Vegetation within the filter should be protected from direct herbicide applications. Certain species may be more tolerant of certain herbicide chemicals. It is also important to keep the strip and its outlet as wide as is possible. The waterway may need reconstruction from time to time to maintain proper shape.

Prioritization for grassed waterway installation and/or maintenance should target the Middle and Upper Little Blue River and Farmers Stream Subwatersheds. Each of these subwatersheds contained multiple locations where grassed waterway installation and/or maintenance could help to improve water quality. Figure 38 depicts the representative need for grassed waterways in the Little Blue River Watershed.

Shallow Water Areas (Wetlands)
Shallow water areas, including ponds and wetlands, within or near farmland provide cover and a water source for wildlife while also acting as a filter. Embankments and berms that pond water increase the land's water storage capacity helping to reduce volumes and flow rates of runoff. Constructed wetlands contribute to water quality improvement by: 1) reducing coliform bacteria by 90% (Reed and Brown, 1992); 2) fostering growth of microbes that recycle and retain nutrients (Wetzel, 1993); 3) providing additional adsorption sites for nutrients through the decomposition of organic matter (Kenimer et al., 1997); 4) providing anaerobic areas where denitrification processes can release nitrogen to the atmosphere; 5) degrading organic materials thereby decreasing biological oxygen demand (BOD); 6) offering sedimentation and filtration processes which remove suspended solids and adsorbed nutrients; and 7) providing flood water storage to attenuate peak flood flows. Tables 43-52 and Figure 30 show where wetland restoration should occur in the Little Blue River Watershed. Priority should be given to wetland restoration in the tributary subwatersheds, particularly Little Gilson Creek, Rays Crossing Tributary, and Manilla Branch Subwatersheds, because of relatively high nitrate-nitrogen concentrations.

Wellhead Protection Area
Wellhead protection areas help assure the quality of public water supplies drawn from wells. Continuous CRP enrollment is available for land within a 2000-ft radius of a public well. Vegetation planted in these areas can further help prevent water supply contamination.

Cover Crops
The use of cover crops, such as winter wheat, prevents soil from being exposed through the winter and early spring months when some of the most pronounced runoff events may occur in Indiana. Cover crops reduce surface runoff by as much as 50% due to increased infiltration (Unger et al., 1998). Reductions in both the dissolved and particulate forms of nitrogen and phosphorus have also been documented.

Livestock Fencing
Livestock, including beef and dairy cattle, pigs, and sheep, graze at over fifty locations along the Little Blue River and its tributaries. (See the Watershed Study Section for specific locations where livestock grazing was identified.) Grazing livestock in riparian areas are indirectly responsible for the loss of density and diversity of riparian vegetation, a decline in water quality, and modification of the aquatic community structure. Unrestricted livestock trample riparian vegetation which results in the conversion of densely-vegetated riparian areas to grass monocultures (Figure 86; Kimball and Savage, 1977). Woody vegetation and deep-rooted perennial herbaceous species are quickly replaced by shallow-rooted, annual plants which provide lower nutritional value to grazing livestock and less streambank protection than their perennial counterparts (Platts, 1996).

Figure 86. Livestock pasture observed along the Little Blue River streambank.

The conversion from woody vegetation to annual, herbaceous vegetation often results in the exposure of large areas of bare soil to the erosive forces of both the livestock and the stream. Mass erosion from trampling, hoof slide, and the resultant streambank collapse causes sediment to move from the streambank into the stream (Binns and Eiserman, 1979). Continued grazing of these unstable areas creates ever-widening channels with more areas of exposed soil (Platts, 1983). Unstable streambanks combined with exposed sediments often result in the transport of additional fine sediments from the streambank to the channel (Armour, 1977). Erosive action by wind and water causes rich topsoil, sediment, and sediment-attached pollutants to move from the streambank into the water causing a decline in the quality of the receiving stream (Platts, 1996). Studies conducted by the Pennsylvania Cooperative Fish and Wildlife Unit indicated that 81% of grazed streambanks suffer from erosion while only 6% of non-grazed streambanks possess similar erosion issues (Wohl and Carline, 1996). Widespread erosion and large areas of bare ground allow pulses of sediment and sediment-attached nutrients to enter the stream with little or no buffering. Changes in magnitude and timing of storm flows; increases in fecal coliform bacteria levels, nutrients and sediments; and decreases in channel depth coupled with increases in channel width also result from grazing (Platts, 1996).

The narrow fringe of vegetation present in riparian areas is essential in maintaining the stream structure necessary to support productive aquatic communities. Poor riparian vegetation density and diversity, high fecal coliform levels, high sediment and nutrient loading rates, and instream sedimentation combine to create poor water chemistry and habitat conditions. Tolerant, less specialized aquatic macroinvertebrates predominate in streams where livestock grazing is prevalent (Phillips and Simpson, 2003). In addition to decreasing the density and diversity of foodstuff in the form of available macroinvertebrates, fine sediment entering the stream along areas of grazing smothers spawning and rearing habitat of fish (Platts, 1983). Furthermore, as vegetation is removed, instream water temperatures increase, thereby creating a gradual shift from low temperature tolerant game fish species to high temperature tolerant non-game species such as carp and bullhead (Platts and Nelson, 1988).

Continuous livestock grazing causes a decline in riparian and floodplain species density and diversity, an increase in channel erosion, an alteration in instream productivity, an increase in sediment movement, an increase in stream turbidity, a decrease in dissolved oxygen, and a modification of the food web structure (Braun et al., 2003). Fencing livestock out of the stream channel and away from riparian vegetation allows plant communities to gradually return to diverse stands of perennial herbaceous and woody vegetation. Streambank protection provided by this vegetation acts as a buffer for overland flow thereby reducing sediment and sediment-attached nutrient loading to the stream, providing more channel and instream cover, and increasing channel stability. The combination of improvements in water chemistry and habitat are likely to result in higher quality, more diverse aquatic communities. High *E. coli* concentrations were observed at the Lower Little Blue River (Site 1), Manilla Branch (Site 3), Beaver Meadow Creek (Site 6), and Farmers Stream (Site 7) sites during this study, while high *E. coli* concentrations have been historically documented in Rays Crossing Tributary, Manilla Branch, and along the Little Blue River mainstem. Priority should target the Lower Little Blue River, Manilla Branch, Rays Crossing, Beaver Meadow Creek, and Farmers Stream Subwatersheds.

Other Conventional Structural Conservation Practices

A wide variety of other conventional structural conservation practices have been prescribed and are in use in various areas of the Little Blue River Watershed. Although not all practices are applicable in every situation, systems of two or more structural BMPs used in concert are often required to achieve the desired conservation benefit. A complete listing of the over 160 different conservation practices recognized by the USDA is available online at http://www.ftw.nrcs.gov/nhcp_2.html. The website offers standards and more details for each practice in a portable document format (PDF) and in MS-Word format. Structural conservation practices that are relevant for use in the Little Blue River Watershed are listed in Appendix J.

Conventional Managerial Conservation Practices
Managerial BMPs are those that involve behavior or decisions made with respect to normal land use operation. Commonly used practices include conservation tillage, rotational grazing, and pesticide management. Managerial conservation practices are often less expensive because they do not involve building a structure; however, successful implementation may require changing habitual behaviors and some trial-and-error experimentation. Several commonly used managerial practices are discussed below.

Conservation Tillage
Removal of land from agricultural production may not be economically feasible in some cases. Conservation tillage offers the potential for reducing erosion without removing the land from production. Conservation tillage is a crop residue management system that leaves at least one-third of the soil covered with crop residue after planting. Table 69 offers a description of the different tillage types. No-till, ridge-till, and mulch-till are all examples of conservation tillage. Figure 87 illustrates calculations of soil loss with respect to the "tolerable" amount of soil (T) that can be lost while still maintaining the productivity of the soil through natural formation processes. On average, all tillage methods exceed the T value for Indiana soils; however, soil loss is less using no-till and mulch tillage.

Table 69. Tillage type descriptions.

Type	Description	% Remaining Residue	Conservation Tillage Type?
No-till/strip-till	soil is undisturbed except for strips up to 1/3 of the row width	>30%	Yes
Ridge-till	4-6" ridges are formed on strips up to 1/3 of the row width	>30%	Yes
Mulch-till	full width of the row is tilled using only one or two tillage passes	>30%	Yes
Reduced-till	full width of the row is tilled using multiple tillage passes	16-30%	No
Conventional-till	full width of the row is tilled using multiple tillage passes	<15%	No

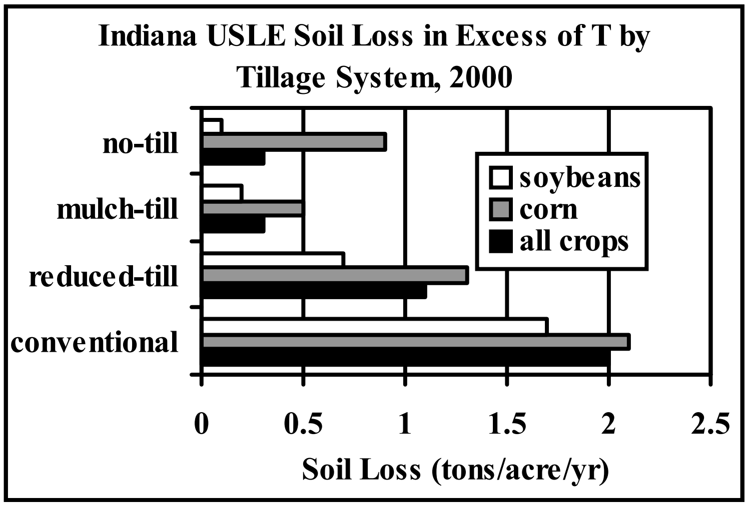


Figure 87. Indiana average USLE soil loss in tons/acre in excess of T by tillage system for 2000. USLE is the Universal Soil Loss Equation. Values shown are in excess of T, which is the "tolerable" amount of soil that can be lost while maintaining the productivity of the soil. Most Indiana soils have a T-value of 3-5 tons per acre per year.
Source: Purdue University, 2000.

Aside from saving time for the producer, a comprehensive comparison of tillage systems shows that no-till results in 70% less herbicide runoff, 93% less erosion, and 69% less water runoff volume when compared to conventional tillage (CTIC, 2000). Reductions in pesticide loading have also been reported (Olem and Flock, 1990). In his review of Indiana lakes, Jones (1996) documented lower lake Trophic State Index (TSI) scores in ecoregions with higher percentages of conservation tillage. A TSI is a score that condenses water quality data in a single, numerical index. Higher scores indicate evidence of eutrophication (overproductivity) or poorer water quality, while lower scores are indicative of better water quality. No-till practices are also good for wildlife. North Carolina researchers have found that crop residues provide the food that quail chicks need to survive the first few weeks of life (Osmond and Gale, 1995). Additionally, conservation tillage reduces carbon dioxide emissions from the soil. Carbon dioxide, the most ubiquitous of the greenhouse gases, is being found at ever-increasing concentrations in the atmosphere and has been linked to global warming.

Agricultural economists with the Ohio State University Extension have reported that farmers adopting conservation tillage in the Maumee and Sandusky River Watersheds saw modest decreases in farm production costs (Indiana Agrinews, 2001). During that same time period, monitoring data showed decreased loading to Lake Erie of many non-point source pollutants that are related to farming. The researchers reported individual farm savings of 2-8% in labor costs and 6-15% in machinery operation costs; however, farmers adopting no-till practices did incur a 10-18% increase in herbicide costs due to lack of tillage for mechanical weed control.

While conservation tillage has been shown to reduce total phosphorus and total nitrogen in surface runoff by as much as 70 and 75% respectively, increased dissolved phosphorus and nitrate losses have been documented (Sharpley and Smith, 1994). In the Sharpley and Smith (1994) study, nitrate concentrations in surface runoff increased from 4.5 to 29 mg/l and dissolved phosphorus concentrations in surface runoff were 300% higher. The increase in nitrate was attributed to increased soil infiltration that occurs with conservation tillage. Higher phosphorus concentrations were attributed to leaching of the nutrient from crop residue and preferential transport of smaller-sized soil particles that is associated with no-till practices. Another study by the Ohio State University Extension also documented 10-15% increases in nitrate runoff to local streams (Indiana Agrinews, 2001) and suggested that conservation tillage time savings allowed farmers to substitute winter wheat planting with corn which requires higher amounts of nitrogen fertilizers.

In 2000, conservation tillage was used on 45% of Indiana's cropland. Even though Indiana is a no-till leader among cornbelt states, data suggest that few fields were no-tilled over the long term. Given that most research suggests that no-till benefits to soil begin to appear no earlier than the 3rd consecutive year of no-till, many farmers are abandoning no-till at about the time one would expect its benefits (Evans et al., 2000). Data from the Purdue Agronomy Research Center suggest that over the past 25 years, cropland where no-till was used in a corn-soybean rotation economically outperformed cropland where conventional, mulch, and strip tillage systems were employed (West et al., 1999). Producers should be encouraged to give no-till practices the continuous time necessary to reap yield, economic, and environmental benefits. Mark Evans of the Purdue Cooperative Extension Agency believes that use of conventional tillage methods increased greatly in 2002 due to extremely wet fall and spring conditions throughout Indiana. Heavy rains enhance rill and gully erosion problems, thereby requiring tillage prior to planting.

Producers that switch to a conservation tillage pattern should keep in mind that the normal planting process and management regime may need to be modified or "fine-tuned" for success. Tillage will no longer destroy weeds before planting and new weed species will likely invade given the different soil conditions. Treating these new invaders may require different herbicides. Certain crop varieties may not tolerate the change in herbicide regime, so a different crop variety may be required. Yield reduction, which at first may be associated with tillage change, may be due in fact to a different level of tolerance to a new herbicide (Canada-Ontario Green Plan, 1997).

Conservation tillage is readily used throughout the study watershed, but farmers should be encouraged to stay with the minimum till practices longer than 2-3 years. The best way to protect against soil loss is to keep the soil covered, minimizing disturbance. As a result of conservation tillage used in combination with other BMPs, 75% of Indiana's cropland is losing soil at or below the tolerable level of T for the 2000 growing season (Evans et al., 2000). In fact, scientific evidence indicates that about 80% of environmental issues that result from cropland can be corrected by integrating BMPs into farm management (CTIC, 1999). The Headwaters, Beaver Meadow Creek, and Little Blue River mainstem Subwatersheds contained the highest total suspended solids and particulate phosphorus loads. Priority for conservation tillage should be targeted at these subwatersheds to reduce overland flow and keep sediment and sediment-attached pollutants in farm fields.

Nutrient Management Research

Nutrient management has been the focus of agricultural research in many parts of the country. Studies have shown that every year about 15% of the applied nitrogen, 68% of the residual nitrogen in the non-root zone layer of the soil, and 20% of the residual nitrogen in the root zone layer are leached to the groundwater (Yadav, 1997). To address this concern, the Penn State Cooperative Extension Service designed a nutrient management plan based on: 1) crop yield goals; 2) soil type; 3) methods of manure and commercial fertilizer application; 4) nitrogen concentrations in soils; 5) nitrogen concentrations in manure to be used for fertilizer; and 6) crop rotations (Hall and Risser, 1993). With this plan in place: 1) fertilizer application as manure and commercial fertilizer decreased 33% from 22,700 lbs/year to 15,175 lbs/year; 2) nitrogen loads in groundwater decreased 30% from 292 lbs of nitrogen per 1,000,000 gallons of groundwater to 203 lbs per 1,000,000 gallons; and 3) the load of nitrogen discharged in groundwater was reduced by 11,000 lbs for the site over a three-year period (70 lbs/ac/yr).

Nutrient Management in the Little Blue River Watershed
Like many agricultural areas, fertilization is an important part of production in the Little Blue River Watershed. Producers generally apply anhydrous ammonia at spring planting and sparingly apply potash in the fall (Scott Gabbard of the Shelby County Purdue Cooperative Extension Agency (PCEA) and Will Schakel of the Rush County PCEA, personal communication). Some producers apply an additional dose of nitrogen when corn is knee high while others apply nitrogen in the fall when corn is planted after soybeans. There are few large animal operations located within the Little Blue River Watershed, but many smaller animal operations are located throughout the watershed. Most manure is pasture applied by cattle in Shelby County (Scott Gabbard, personal communication); however, managed manure application does occur in the portion of the watershed in Rush County (Will Schakel, personal communication). Many livestock producers are located within the Little Blue River Watershed because topography and soils inhibit row crop production in this area. Livestock access to the Little Blue River and its tributaries should be limited through the fencing of livestock and creating alternative livestock watering sources. Figure 30 maps specific areas throughout the watershed where livestock currently have access to the stream.

Management of nutrients in fertilizer can greatly benefit water quality. The first step in effective nutrient management is regular soil testing. Historically, producers conducted soil tests only when a problem was noticed. More recently soil testing has occurred every 3-5 years (Will Schakel, personal communication). In some sections of Shelby County, soil testing occurs every 2-3 years; in most cases soil testing frequency is dependent upon the producer with some producers testing much more frequently than others (Scott Gabbard, personal communication). Soil tests typically include detection of soil phosphorus, potassium, lime content, pH, and nitrogen. Because nitrate-leaching risk is moderate to high throughout much of the watershed, special efforts to apply soil-appropriate levels of nitrogen should occur, specifically in the Beaver Meadow Creek headwaters, the Little Blue River headwaters east of State Road 3, and along the Little Blue River mainstem from Arlington southwest to Shelbyville. Priority should be given to wetland restoration in the tributary subwatersheds, particularly Little Gilson Creek, Rays Crossing Tributary, and Manilla Branch Subwatersheds, because of relatively high nitrate-nitrogen concentrations.

Fertilizer should be applied based on realistic yield goals. Scott Gabbard (Shelby County PCEA) believes that most farmers in the area fertilize based on realistic expectations; however, due to the variability associated with weather patterns and Shelby County soils, application based upon realistic goals is not always possible. Will Schakel (Rush County PCEA) believes that most producers are fertilizing “on the low side of realistic goals” due to the cost associated with fertilization and the small profit margin that most farmers are currently experiencing. Producers should also make allowances in nitrogen application for nitrogen contribution of any previous legume crops in the rotation or any legume cover crops. Gabbard stated that most farmers in Shelby County use a corn-soybean rotation; Schakel stated that corn-soybean-hay/forage rotations are in use throughout Rush County and that most of the producers do account for legume nitrogen additions in their fertilizer regimes. Fertilizer adjustments may also be necessary when transitioning from conventional to conservation tillage.

In special areas of environmental concern, such as fields that border streams and other waterbodies, fertilizer setbacks should be utilized. Setbacks are strips or borders where fertilizer is either not applied or applied in smaller quantities. Fertilizers should not be applied directly next to streams and certainly not in them. According to the Shelby County PCEA, fertilizer setbacks are accomplished with filter strips; most farmers are conscientious of application near tile drains and open ditch areas. Will Schakel stated that filter strips are not commonly used in Rush County, but that farmers are extremely aware of fertilizer application near streams and drainage tiles. Producers on highly erodible land in some areas of concern tend to be more conscientious with respect to fertilizer application; many of these producers are diligently following their production plans and continue to maintain highly erodible field in hay or wheat and avoid tilling these fields in the fall.

Though not a nutrient in and of itself, *E. coli* bacteria contamination of waterways is an indirect effect of applying animal waste as fertilizer. *E. coli* and other bacteria from the intestinal tracts of warm blooded animals can cause gastroenteritis in humans and pets. Symptoms of gastroenteritis include: nausea, vomiting, stomachache, diarrhea, headache, and fever. Due to high E. coli counts, about 81% of the assessed waters in Indiana did not support “full body contact recreation” in 1994-1995 (IDEM, 1995). Of over 800 samples collected in the St. Joseph River (Ft. Wayne) in northern Indiana during 1996-1997, the average of all samples was 2000 colonies/100 ml, or about 16 times the maximum allowable level (Frankenberger, 2001). Samples collected near 19 USGS gauging stations in the St. Joseph River (South Bend) Watershed during 2002 contained *E. coli* concentrations of 7-4,600 colonies/100 ml. The USGS determined that 33-95% of these colonies were to be pathogenic strains (O157:H7) of *E. coli* (Duris et al., 2003). During the present study, many of the Little Blue River Watershed streams were in violation of the Indiana state standard; concentrations ranged from 66-18,000 colonies/100 ml (Table 56). To prevent manure from entering tiles, ditches, and streams, producers can: 1) apply manure at optimal times for plant uptake; 2) apply manure when potential for plant uptake is high and runoff is low; 3) inject or incorporate manure to reduce runoff potential; 4) use filter strips; and 5) use setbacks from surface inlets to tile lines.

Weed and Pest Management
Groundwater data assembled by the USGS and the USEPA found 18 pesticides and five pesticide breakdown products in 9% of the samples taken in Indiana (Goetz, 2000). Modeling by Purdue University professor Bernie Engel, showed that 75% of detectable pesticides in groundwater came from 25% of farmland. Figure 19 shows areas of the Little Blue River Watershed that are vulnerable to pesticide leaching according to modeling work conducted by Purdue University engineering professor Bernie Engel. Areas of concern include the headwaters

of the Little Blue River west of State Road 3, the headwaters of Beaver Meadow Creek, and the lower portion of the mainstem of the Little Blue River from just south of Arlington to the streams confluence with the Big Blue River.

Weed and pest management results in fewer herbicide and pesticide applications at reduced rates and thereby helps to protect the environment by reducing polluted runoff and producers' operating costs. Proper management of these chemicals entails: 1) being familiar with the threshold at which weed and pest populations begin to cause economic damage; 2) using local weather forecasting to time field scouting to determine if pest problems are great enough to warrant the use of a control measure; 3) planting cover crops to suppress weed growth; 4) planting seed that has been bred for pest resistance during optimal conditions; 5) using insect traps near target crops to track infestations; 6) promoting and attracting natural enemies that help control pests; and 7) applying the most effective and appropriate pesticide or herbicide during optimal weather conditions.

Properly functioning tile lines have been shown to reduce pesticide contamination of water by decreasing runoff so less pesticide is carried in water and by soil particles adsorbing many of the chemicals as water runs through the soil on its way to tiles (Goetz, 2000). Compared to pesticide runoff in surface water, relatively little soaks down through the soil into the groundwater (Kladivko, 1999). Although it may vary with soil type, the amount of pesticide that enters tile lines is generally less than half a percent of the amount applied. Meanwhile, surface runoff from poorly drained fields during the first or second storm after application can contain 1-2% of the pesticide applied. Based on her research Purdue agronomy professor Eileen Kladivko recommends that farmers properly tile poorly drained fields if they are to be used for production to avoid possible surface water contamination with pesticides (Goetz, 2000).

In both Rush and Shelby Counties, herbicides are applied based on season and weather patterns, while pesticide is applied based on need. In Shelby County, herbicide application is typically applied from April to June (Scott Gabbard, personal communication). Insect scouting is a cooperative effort between farmers and pesticide applicators. In Rush and Shelby Counties, farmers conduct most of the insect scouting. If problems with insects are discovered, then the Farm Bureau, a professional scout, or agronomist provides assistance to producers. According to the Rush County Purdue Cooperative Extension Agency western corn rootworm, earworm, army worms, and Japanese beetles are the most common pests. Slug damage in areas near waterways is common in much of Shelby County (Scott Gabbard, personal communication). Interestingly, an additional advantage of crop rotation (which is avidly used within the study area) helps to break the annual life cycles of most typical crop insects (Jeff Burbrink of the Elkhart County Purdue Cooperative Extension Agency, personal communication).

Resource Management Planning

Resource management planning is an individually based natural resource problem solving and management process advocated by the NRCS (NRCS, 2001). It addresses economic, social, and ecological concerns to meet both public and private needs while emphasizing desired future conditions. NRCS personnel work directly with individual landowners to meet his or her objectives to ensure that all parties understand relevant resource problems and opportunities and the effects of decisions. The process has three phases and nine steps:

Phase I – Collect and Analyze
1. Identify Problems and Opportunities
2. Determine Objectives
3. Inventory Resources
4. Analyze Resource Data

Phase II – Decision Support
5. Formulate Alternatives
6. Evaluate Alternatives
7. Make Decisions

Phase III – Application and Evaluation
8. Implement the Plan
9. Evaluate the Plan

Though not widely used, Resource Management Plans have met with success in most areas. According to Doug Nusbaum, an agriculture conservation specialist with the Indiana Department of Natural Resources (personal communication), most if not all fields (including highly erodible ones) can be responsibly managed and used for production with the development of a Resource Management Plan. Planning involves inventorying the resources, communicating with the landowner about where improvements may be made, and implementing the plan.

Other Conventional Managerial Conservation Practices
The USDA has published specifications for management-oriented practices in addition to the more common ones described above. Again not all practices are applicable in every situation, but managerial BMPs used in concert with structural BMPs are often required to meet conservation goals. A list of the various conservation practices recognized by the USDA is available online at http://www.ftw.nrcs.gov/nhcp_2.html. Managerial conservation practices that are relevant for use in the Little Blue River Watershed are listed in Appendix J.

Innovative/Newly Developed Conservation Practices
Researchers interested in agriculture and conservation are testing new ideas for production management every day in the United States and Canada. A comprehensive literature search was conducted as part of the current study. BMPs that may present promise of water quality benefit in certain situations are presented below. It should be noted that some of the practices have been developed fairly recently and successful results cannot yet be guaranteed.

Riparian Management System Model
The Agroecology Issue Team of the Leopold Center for Sustainable Agriculture and the Iowa State University Agroforestry Research Team banded together in the early 1990s to promote restoration of the Bear Creek Watershed in central Iowa via development of a riparian management system model. Results of their study provide valuable lessons relative to management decisions and practices in the Little Blue River Watershed. The purpose of the study was to design a management system composed of several parts so that each part could be modified individually to meet site conditions and landowner objectives. Specific goals of the management system include: interception of eroding soil and agricultural chemicals, slowing of flood waters, stabilization of streambanks, and provision of wildlife habitat and an alternative, marketable product (Isenhart et al., 1997). The system model consists of a multispecies riparian

buffer, streambank stabilization, a constructed wetland, and a rotational grazing strategy (Figure 88).

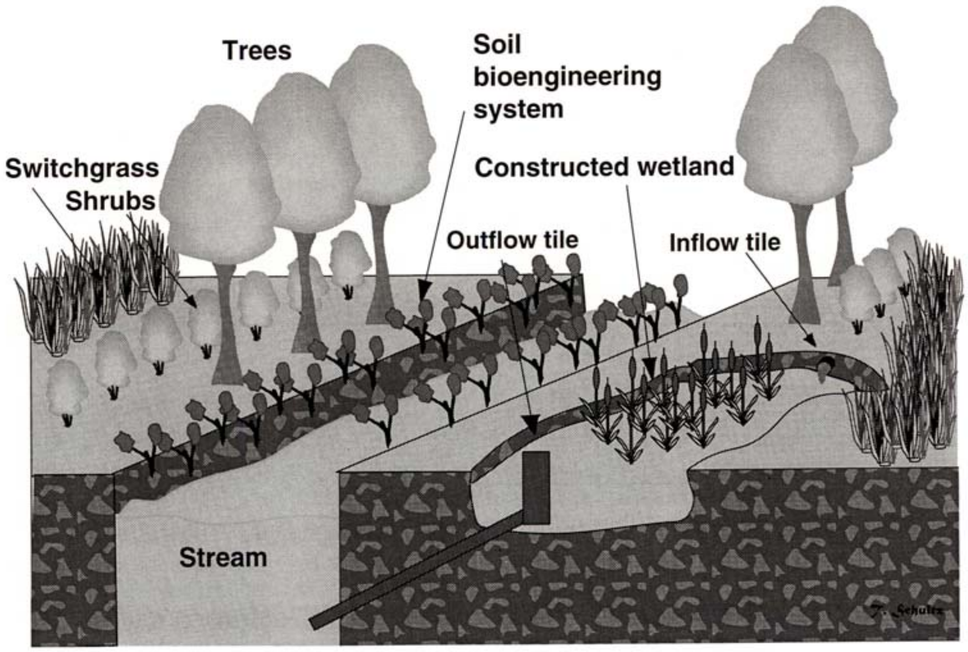


Figure 88. The riparian management system model (Isenhart et al., 1997). Used with permission from the American Fisheries Society.

The riparian buffer strip component consists of three zones (Figure 89): 1) A 33-foot-wide strip of trees bordering the stream. Fast-growing, native species like green ash, willow, poplar, and silver maple are recommended. Slower-growing trees like oaks and walnuts may be planted in the outer edge if desired. 2) A 12-foot-wide strip of shrubs. Shrubs, like trees, have permanent rooting structures and offer habitat diversity. Recommended species include ninebark, redosier and gray dogwood, chokeberry, witch hazel, nannyberry, and elderberry. 3) A 21-foot-wide strip of warm-season grasses. Species mixes were discussed in the filter strip section. Altogether the strip is 66 feet wide, but each component may be altered to address landscape requirements, desired physical and/or biological functions, landowner objectives, and cost-share program standards. Appendix K includes before and after pictures of a riparian management system installation site in the Bear Creek Watershed.

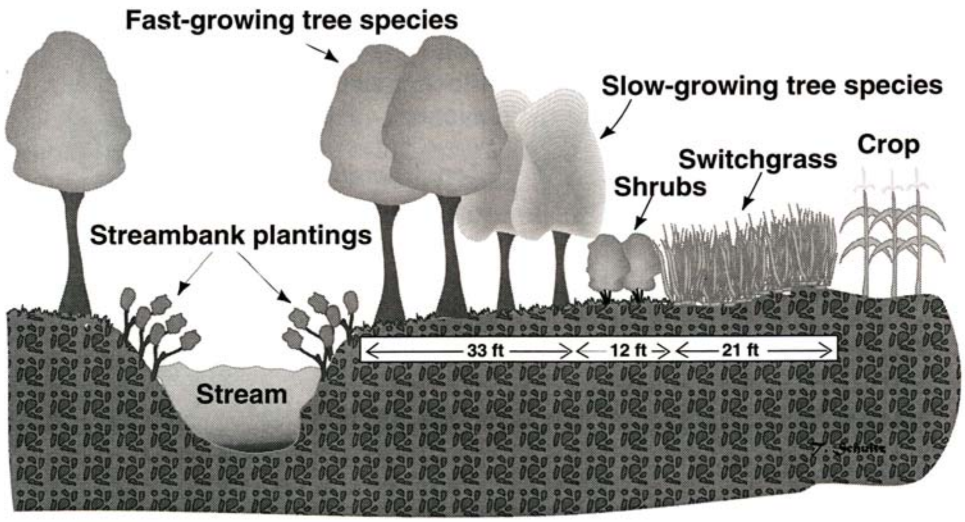


Figure 89. The multispecies riparian buffer strip component of the management system model. Used with permission from the American Fisheries Society.

Streambank stabilization using bioengineering techniques is the second component of the comprehensive riparian management system model. Feasible techniques include installation of native, live plant material in combination with revetments of rock or wood and biodegradable erosion control fabric. According to Klingeman and Bradley (1976) bank vegetation provides numerous stabilization benefits such as: 1) plant roots holding soils together and in place; 2) above-ground vegetation increasing surface flow resistance, decreasing flow velocities and routing energy dissipation toward plant material and away from soils; 3) vegetation buffering the channel from abrasion by materials transported from upstream; 4) vegetation inducing sediment deposition, helping to keep soil on the land and to rebuild streambanks.

The final two components of the model include a constructed wetland designed to fit into the 66-foot buffer strip and a rotational grazing system to control livestock stream access. Constructed wetlands have a known track record for nitrate removal (via the process of denitrification) from surface water. In the Iowa study, water from a 12-acre field discharged into a 2,900 ft^2 (<0.10 acre) wetland. A gated tile at the outlet of the wetland provides control of water levels (Figure 89). Vegetation was planted in the wetland to jump-start nutrient uptake. (See Appendix K for photo and Table 70 for a list of plants recommended for wetland planting.) Other studies suggest that a wetland area to cultivated crop area ratio of 1:100 will provide the water retention time during normal runoff events necessary to remove a significant amount of nitrate.

Table 70. Plant species suitable for filtration and nutrient uptake in restored or constructed wetlands.

Grasses	**Forbs**
Redtop	Sweet flag
Creeping bent grass	Common water plantain
Spike rush	Cardinal flower
Common rush	Great blue lobelia
Rice cut grass	Monkey flower
Soft-stem bulrush	Arrow arum
Bur reed	Smartweed
Temporary Grasses	Pickerel weed
Seed oats	Broad-leaf arrowhead
Annual rye	

*Note: Seed the permanent grasses at 3 lbs/acre, the temporary grasses at 42 lbs/acre, and the forbs at 2.75 lbs/acre.

Monitoring is an important part of any study, and as such, the Bear Creek project sites were monitored for success (Isenhart et al., 1997). The monitoring studies indicated that the 21-foot-wide switchgrass component of the model reduced sediment load to the stream by 75%. Nitrate-nitrogen concentrations moving in groundwater below the buffer were markedly lower than those moving below the adjacent, cropped field. Nitrate levels below the buffer never exceeded 2 mg/l while levels below adjacent cropped fields consistently exceeded 12 mg/l (Schultz et al., 1995). In contrast, groundwater nitrate concentrations in a field cultivated to the stream's edge showed no reduction nearer the stream. Wildlife use of the restored area was also markedly improved. While only four bird species per day were observed in channelized reaches, 18 species per day were recorded in 4-year-old buffer sections. Additionally, constructed wetland outflow concentrations of nitrate-nitrogen were significantly lower than inflow concentrations during most sampling periods.

The Iowa management system model provides valuable lessons for management within the Little Blue River Watershed. The approach is flexible for site-specific conditions and respectful of private landowners' desires and objectives. Within the Bear Creek Watershed, two relatively small sites were initially built and then used to garner the interest and support of other landowners. Similar management system models hold great promise for application within the study watershed and include the following major advantages: 1) interception of eroding soil, 2) trapping and transformation of non-point source pollution, 3) stabilization of stream banks, 4) provision of wildlife habitat, 5) production of biomass for on-farm use, 6) production of high-quality hardwood, and 7) enhancement of agro-ecosystem aesthetics (Schultz et al., 1995).

Natural Nitrification Stimulation

Growers Nutritional Solutions of Milan, Ohio has researched and recommends a nutrient management plan that stimulates natural nitrification processes in the soil. The program has been recognized by the Environmental Protection Agency as having environmental benefits because less commercial nitrogen needs to be applied (Halbeisen, 2001). The plan has applications and can be used in both agricultural and residential lawn care situations.

The natural nitrification program involves supplying adequate amounts of calcium to the soil profile and foliar fertilization using high-grade, balanced fertilizer solutions. Research shows that calcium: 1) stimulates nitrogen-fixing soil bacteria like *Azotobacter* which can fix 15-40 lbs of nitrogen/acre/year (Smith et al., 1953); 2) prevents increased solubility of iron and aluminum which negatively affects nitrogen fixation; 3) increases soil porosity and oxygen exchange which are important for the conversion of nitrogen to a form that can be used by plants; and 4) stimulates earthworm populations, which shred organic matter for bacterial consumption and help to decrease soil compaction. The second part of the program requires applying a small amount of balanced fertilizer on the seed at planting. The crops are then fed through the foliage at certain stages of development. Research shows that foliar-applied fertilizer is used more efficiently than soil-applied nutrition (Joint Committee on Atomic Energy, 1954). Advantages of using the two part program include: 1) lowered use of applied nitrogen, 2) sound economic productivity, 3) higher grain weights, 4) better produce flavor and shelf life, and 5) fewer livestock veterinary visits (Halbeisen, 2001).

Integration of Nitrogen and Phosphorus Management

Recent research has suggested the need for integrated nitrogen and phosphorus management to account for spatial variation in nutrient loss risk (Heathwaite et al., 2000). While nitrate-nitrogen loss from landscapes is a threat to groundwater supplies, phosphorus loss threatens rivers, lakes, and oceans with eutrophication (overproduction). Nitrogen as nitrate is highly mobile in leaching water and is primarily lost through subsurface runoff. (Figure 18 shows areas of the Little Blue River Watershed that are vulnerable to nitrate loss via leaching according to modeling work by Purdue University engineering professor Bernie Engel.) On the other hand, phosphorus is predominantly lost via surface runoff. Because the two nutrients are transported by such different mechanisms, different management tools should be employed depending on which nutrient is of the highest risk of being lost. For example, it does not make sense to prioritize management of phosphorus in an area of the watershed that rarely contributes surface runoff and that does not receive high amounts of the nutrient. Different sections of even a single tract of land may need to be managed differently based on risk of nutrient loss.

In many cases, "across-the board" management of only one nutrient may in fact heighten the risk of pollution by the other. For example, when manure fertilization regimes are based on soil nitrogen content alone to manage nitrate leaching, phosphorus is often over-applied. The amount of phosphorus applied relative to nitrogen (N:P = 2:1 to 6:1) is often greater than that which can be taken up by crops (N:P = 7:1 to 11:1) (Eck and Stewart, 1995). In contrast, use of artificial drainage to reduce phosphorus loss by reducing surface runoff may enhance nitrate leaching through the ground (Turtola and Paajanen, 1995).

Individual tracts of land can be assessed for nutrient loss risk by applying nitrogen and phosphorus indexing systems to assign risk ratings (Heathwaite et al., 2000). The nitrogen index is based on soil texture and permeability, fertilization rate and method, and manure application rate and method. The phosphorus index is based on erosion potential, amount of runoff that leaves the site, distance from the site to the nearest waterway, soil test phosphorus, fertilization rate and method, and manure application rate and method. By calculating the index value for each nutrient, loss vulnerability for the site can be determined and management tailored accordingly.

In areas that are phosphorus-loss prone, fertilizer and manure applications should be appropriately modified and features that slow surface runoff should be installed (i.e., constructed wetlands and filter strips). In areas where nitrogen loss is a hazard, nitrogen sources and sinks like fertilizer, crop type, and crop rotation should be carefully monitored. Different management priorities may be suited to different areas of a watershed or tract of land.

Water Treatment Residual Application to Reduce Nutrient Loss
Recent research shows that residual chemicals produced during the drinking water purification process may retard nutrient loss from animal wastes applied as fertilizers (Gallimore et al., 1999). Water treatment residuals (WTR) are composed of sediment, aluminum oxide, activated carbon, and polymer. Runoff from plots fertilized with poultry litter including WTRs contained 50% less dissolved phosphorus and 66% less ammonium when compared to runoff from control plots which received poultry litter alone. Land application of the WTR did not increase total dissolved solids or aluminum concentrations in surface runoff. The study did note, however, that WTR may damage pasture vegetation and is discouraged in these locations (Gallimore et al., 1999).

Systems of BMPs
Although individual BMPs are commonly and have traditionally been used, recent work shows that BMPs used in concert working as a system will often be more effective at pollution control than individual practices (Osmond et al., 1995). Systems of BMPs function to minimize the pollutant at several points including the source, the transport process, and the water body. For example, the goal of an Iowa Rural Clean Water Program (RCWP) project, was to protect Prairie Rose Lake from the sediment it was receiving from the surrounding watershed. Two BMPs, critical area planting and conservation tillage, were used to diminish soil loss from agricultural land, while five BMPs including terraces, underground outlets, diversions, grassed waterways, and detention basins, were constructed to slow sediment transport to the lake (Osmond et al., 1995).

8.1.2 Urban/Residential Best Management Practices
The urban landscape can contribute more pollutants to nearby waterbodies than some agricultural landscapes. The U.S. Environmental Protection Agency's National Urban Runoff Program (USEPA, 1983) results suggest that pollutant runoff rates, including nutrients and suspended solids, will increase as land is converted from agricultural fields to urban landscapes. Reckhow and Simpson (1980) found similar results in their review of studies of nutrient export rates from various landscapes. Bannerman et al. (1993) reported that streets and parking lots release significant amounts of stormwater contaminants. Given the potential for water pollution from typical urban landscapes, watershed stakeholders must also focus on urban watershed management. Addison Township, specifically Shelbyville, has undergone continuous growth since the mid-1900s. The city and its residents can help to improve water quality in the Little Blue River through efforts listed in the following paragraphs, which describe several residential watershed management techniques and best management practices that are applicable to Shelbyville and the Little Blue River Watershed.

Septic Systems/Sewers

The reliance of septic systems throughout much of the Little Blue River watershed to treat residential wastewater is of concern. Soil maps of the watershed indicate that a majority of soils are ill-suited for septic systems (Brock, 1986; Hillis and Neeley, 1987; Brownfield, 1991). Many houses are located adjacent to the Little Blue River; however, soils along the length of the Little Blue River are moderately to severely limited for wastewater treatment. Much of the length of the river consists of strongly sloping Miamian soils which should not be utilized for septic systems. Other houses are sited in Crosby soils which, given their high water, should never be used as a septic field. It is likely that many of the septic systems in the unsewered areas of the Little Blue River watershed do not adequately treat wastewater.

Overloaded or leaking septic systems deliver nutrients, pathogens, and oxygen demanding substances to the streams. This can increase the streams' productivity, threaten human health, and impair the streams' habitat. The seepage of untreated or inadequately treated sewage to the Manilla Branch may be one of the reasons for this streams high *E. coli* concentrations and phosphorus levels relative to other streams. Historically, the Manilla Branch possessed poor water quality as evidenced by high nutrient and bacteria concentrations (1,100-2,400 col/100 ml, RCHD). Although the Manilla Branch subwatershed is small (2,923 ac or 1,183 ha) its land use is primarily agricultural. The town of Manilla is the sole urban area in the watershed. Site inspection revealed that houses throughout Manilla are sited in areas where wastewater treatment through the use of septic systems may be difficult. Treaty silty clay loam and Crosby silt loam soils cover the entire incorporated area. Neither of these soils should be used as septic fields. Septic failure in these soils is expected and the consequence of this failure is the delivery of nutrients, pathogens, and other oxygen demanding substances to the Manilla Branch. Eventually, Manilla will be connected to the Western Rush County Sewer District, which will treat the town's wastewater before returning it to a surface waterbody. Until then, nutrients, sediment, and bacteria will continue to be delivered to the Manilla Branch and, ultimately, the Little Blue River.

There are several steps property owners can take to help minimize the problems posed by septic systems. First property owners should conduct regular septic tank maintenance. This means homeowners should have their tanks pumped once a year. For forgetful residents, many septic companies have programs in which the company automatically comes out once a year. Residents should use extreme care when flushing household cleaners or "septic cleaners" down the drain. Many of these products interfere, or worse, incapacitate or kill the bacteria needed to decompose the sewage. Water conservation measures such as using low-flow toilets or taking shorter showers will also decrease the loading to septic systems.

Alternatives to septic systems exist and should be considered. For example, wastewater wetlands typically produce cleaner effluent at the end of a leach field than traditional septic systems. This is particularly true during the summer months when plants in such a wetland operate at peak evaporation capacity. Very little effluent leaves the wetlands. This reduction in effluent released corresponds with the peak times for potential algae and plant growth in the streams. The wetland is working the hardest to prevent nutrients from reaching the streams at the exact time nuisance blooms could develop if sufficient nutrients are present. Leach fields of wastewater wetlands are smaller than traditional leach fields making them more attractive on lots where space is limited.

Wastewater wetlands may be an option at Kennedy Park or the 4-H Fairgrounds. Furthermore, a wastewater wetland can remove large amounts of nitrate-nitrogen, thereby reducing the amount that is delivered to the groundwater. This is of particular concern in and around Shelbyville where the nitrate leaching potential is high.

Despite the presence of maintenance and alternative treatment systems options, ultimately the urban portions of the Little Blue River watershed must possess some type of sanitary sewer system to convey the area's wastewater to an appropriate treatment facility. Residents in more rural areas within the watershed should investigate alternative treatments to overcome the limitations of septic systems. Unlike atmospheric deposition and some groundwater pollution, area residents can control nutrient and pathogen delivery via urban sewer systems and rural alternatives to septic systems. The solution is expensive, but possible. A sewer system in urban areas would eliminate a portion of the nutrient load to the streams', improving the streams' water quality and limiting their productivity.

Streambank Stabilization

Streambank stabilization is of concern in both the agricultural and urban portions of the Little Blue River Watershed; however, more streambank stabilization efforts should be targeted along the lower portions of the river where erosion of is more concern. Incised stream channels are common in the agricultural watersheds of many of the Little Blue River's tributaries. Figures 72 and 79, photos of Rays Crossing Tributary and Little Gilson Creek, respectively, demonstrate typical incised stream channels within the Little Blue River Watershed. Conversion of forested land to agricultural land decreases the landscape's infiltration capacity and increases the volume of water reaching a watershed's streams. The increased volume of water flowing in a stream scours the streambed, lowering the channel bed. This, in turn, increases the channel's capacity. With greater capacity, high volume flows remain in the stream channel rather than overflowing into the adjacent floodplain where the erosive energy of flow could be reduced. Instead, the erosive energy is focused on the channel bed and banks, leading to increased channel down-cutting and eventually the development of a new floodplain at a lower elevation.

Stabilizing and raising the stream channel would interrupt this negative feedback loop by preventing future down-cutting and reconnecting the stream to its floodplain. During high flow periods, water would be released from the channel to the floodplain. Once in the floodplain, water velocities would decrease allowing sediment and sediment-attached pollutants to settle out of the water column. Stabilizing and raising the stream channel would thus decrease bed and bank erosion at the many streambank erosion sites and help reduce sediment and sediment-attached pollutant loading from the tributaries to the Little Blue River.

Larger streambank erosion areas, such as those at the proposed Shelbyville park, require additional stabilization techniques. Bioengineered solutions including cribwalls, soil encapsulated lifts, and willow staking would help hold the soil in place while allowing shrubs and trees to revegetate the streambank. Many of the lower portions of the Little Blue River would benefit from some form of bioengineering (Figures 90 and 91).

Figure 90. Area of streambank erosion observed along the lower reaches of the Little Blue River.

Figure 91. Area of streambank erosion observed along the lower reaches of the Little Blue River.

Trash

The amount of trash observed along the length of the Little Blue River is of concern. Large numbers of tires, large appliances such as refrigerators and air conditioners, and used furniture were noted at several locations along the length of the Little Blue River. Smaller trash items including aluminum cans, plastic bags, candy wrappers, and other miscellaneous items littered several of the sample sites at many of the waterbodies within the Little Blue River Watershed. Decaying trash increases the biological oxygen demand on the stream. Low (or no) oxygen limits habitat availability for fish and other aquatic organisms. Additionally, the trash in the streams may contain toxic substances. Refrigerators and air conditioning units observed in the stream could contain at least trace amounts of toxic substances. These toxic substances could impair several uses of the stream.

It is important to note that the trash problem is a shared problem. Trash was observed at nearly every stream sampling site. Because the trash is a shared problem of all the streams, all watershed stakeholders together should make a concerted effort to prevent the introduction of trash to the streams. In addition stakeholders should organize community clean up days, perhaps enlisting local schools or scouting organizations to help with the effort. Large trash items will require more resources and equipment to remove; however this task should be completed to protect the health of the streams.

The Shelby County SWCD in concert with the Shelbyville Parks Department and the Shelby County Solid Waste Management District has adopted a portion of the Little Blue River. The reach, which runs from the county fairgrounds to Kennedy Park, was cleaned of trash and debris in September. Over 4.5 tons of rubbish was removed at that time. Additional, annually scheduled service days like these can help improve the quality of the stream.

Buffers

Riparian buffers are important in residential areas as well as agricultural areas. Individual landowners installing streamside or pond side buffers can help to improve water quality. Additionally, healthy buffers are attractive additions to residential property. Healthy buffers around any waterbody are important for protecting water quality in a watershed. Vegetative buffers slow overland flow and reduce flow volume by increasing infiltration of runoff. This supports the ecosystem's natural hydrological regime that existed prior to development along the streams. Buffers also help filter sediments, nutrients, pesticides, pathogens, and other pollutants from runoff, preventing these pollutants from reaching the streams. Buffers can reduce up to 80% of the sediment, 50% of the phosphorus, and 60% of the pathogens in runoff (Conservation Technology Information Center, 2000). Buffers immediately adjacent to the streams also protect the streams from scouring action thereby limiting erosion, release oxygen to the water column for use by aquatic biota, and provide food, cover, and spawning/nesting habitat for a variety of fish, waterfowl, insects, mammals, and amphibians. Additionally, large, tall buffers along the streambank, particularly along the Little Blue River's reservoirs, can discourage nuisance waterfowl, such as Canada geese, from taking up residence in the area. Canada geese prefer maintained lawns because they are easy to access from the water and any predators are clearly visible in lawn areas. Lawns also provide a vast food resource for the geese. Native vegetation is higher in profile than maintained lawns and has the potential to hide predators, increasing the risk for the geese. Some native vegetation such as blue iris and cattails are stiff, making it difficult for geese to access the lawn behind the vegetation.

Given the relatively high nutrient concentrations observed in the Little Blue River, the installation of buffer zones along the stream should be a priority. One area that would strongly benefit from the installation of a shoreline buffer is the Little Blue River's southern shoreline at Kennedy Park. As the photo below (Figure 92) indicates, the manicured turf grass of Kennedy Park extends to the water's edge with no emergent buffer between the stream and the park. Any fertilizers or pesticides that may be applied to the park can simply wash right into the Little Blue River, degrading the stream's water quality. In addition to nutrient and pesticide input, leaves and grass clippings also wash into the stream. These organic materials increase turbidity and utilize oxygen in the water column as they decompose. The water quality assessment for the Little Blue River showed that the stream carries relatively high sediment and nutrient loads. The lack of buffers along the stream contributes to this impairment. The easy access to a food source also makes the Kennedy Park area attractive to geese. Geese, in turn, contribute to the nutrient and pathogen loads to the stream. The installation of an emergent and shoreline buffer along the Little Blue River would likely alleviate much of the pollutant loading from Kennedy Park.

Figure 92. Manicured grass adjacent to the Little Blue River at Kennedy Park.

Planting warm season grasses around many of the reservoirs found along the mainstem of the Little Blue River could also improve water quality. Warm season grasses provide shoreline stabilization that is not typically observed with mowed turf grasses. Additionally, the installation of these grasses will limit Canada goose access to the reservoir, thereby reducing one source of pathogens and nutrients to the stream. Figure 93 shows one of the reservoirs where warm season grass planting could improve water quality.

Figure 93. Reservoir along the mainstem of the Little Blue River which could benefit from warm season grass planting.

Additional Treatment of Stormwater Runoff

In addition to proper management of the landscape, watershed stakeholders might consider working with the City of Shelbyville to obtain more treatment for stormwater after it enters individual storm drains. Typical urban stormwater contains high levels of nutrients, sediment, and other pollutants that are harmful to stream ecosystems, and it is likely that stormwater from the newly constructed Walmart shopping plaza is no exception. City planners and engineers commonly recommend detention basins to treat stormwater. Properly designed wet detention basins can remove 79-91% of the total suspended solids and 49-76% of the total phosphorus released to the basin (Winer, 2000).

The potential for retrofitting some of the hard surfaces, mainly the commercial development near the intersection of State Road 44 with Interstate 74, with stormwater Best Management Practices (BMPs) that promote infiltration should also be investigated. This is especially true for the areas where soils are appropriate for infiltration BMPs. Filtration trenches, sand filters, and biofilters (a variation of sand filters that are planted with native vegetation to allow additional nutrient uptake) provide good treatment for stormwater pollutants. Research (Winer, 2000) suggests these infiltration BMPs are particularly good for treating pollutants of concern in the Little Blue River Watershed, phosphorous and sediment. These BMPs also promote infiltration of stormwater rather than storing it and discharging it at a later time. This simulates the natural hydrology of the watershed by recharging the groundwater with at least a portion of the stormwater rather than sending the whole volume downstream. Unfortunately, these BMPs can be costly and difficult to maintain, factors that should be balanced with the benefits derived from these BMPs.

Future Development

Developable land exists in the Little Blue River Watershed. Many of the same urban BMPs listed above can be applied to future residential and commercial developments; however, other measures may be taken during development phases to protect the ecological health of the Little Blue River. These measures typically fall into one of three categories: limiting imperviousness of the development, focusing on stormwater pollutant source and conveyance reduction, and designing site-specific developments. The following paragraphs described these three categories.

Limit Imperviousness

As areas are developed for residential and commercial use, roads, driveways, sidewalks and parking lots replace forested areas and active or fallow farm fields. While these impervious surfaces provide better "car habitat", they do not provide the same filtration and infiltration of stormwater as the vegetation does. Bannerman et al. (1993) found streets and parking lots to be "critical sources" of stormwater contaminants in their study conducted in Madison, Wisconsin. Impervious surfaces also concentrate stormwater pollutants and increase runoff velocities while conveying the water. This alters the natural hydrology of the watershed and typically increases pollutant loading to receiving waterbodies. Research suggests that the water quality of receiving waterbodies begins to deteriorate once 10% of a waterbody's watershed is covered with impervious surfaces. Setting a goal of less than 10% impervious surface coverage is possible in the Little Blue River Watershed; all efforts should be made to limit the amount of impervious surface to only that absolutely necessary.

Several techniques are available to land planners to reduce the amount of impervious surfaces in new development. For example, planners can employ conservation design in residential areas. These design patterns cluster housing units together leaving more open space to buffer the impacts of the development. Subdivision designs should minimize street length in the housing layout and avoid cul-de-sacs without open centers. Residential street width and parking lot size should be also minimized. Although not always popular, shared driveways reduce pavement in residential areas as well. Porous pavement should be utilized in low traffic areas such as sidewalks and overflow parking areas of commercial developments. These are just of few of the possible alternatives for reducing the amount of impervious surfaces in a watershed.

Stormwater Pollutant Source and Conveyance Reduction
Many of the best management practices utilized in the existing commercial and residential developments, such as detention basins, treat stormwater volume and pollutants at the end of the line. Equal consideration should be given to practices that limit the creation or source of pollutants and practices that treat stormwater in route to an end-of-the-line treatment structure. For example, where site conditions allow, curb and gutter systems should be replaced with grassed shoulders and roadside swales to promote vegetative uptake of pollutants and infiltration of stormwater prior to its release in a detention basin or storm sewer. This would reduce both the amount of pollutants and volume of stormwater that the detention basin needs to treat. Curb and gutter systems do not provide any treatment of stormwater in route to the-end-of-the line structural BMP.

Reduction of pollutants at their source is especially important considering that many of the structural stormwater BMPs have limitations on their pollutant removal capacity. Many stormwater BMPs report good pollutant removal efficiencies. As cited above, wet detention basins can remove close to 80% of the total suspended solid load to the basin. Unfortunately, over time the 20% that passes through may be sufficient to accelerate the degradation of sensitive ecosystems downstream of the BMP. In his examination of stormwater practices, Schueler (1996) identified the “irreducible” concentration of several typical stormwater pollutants discharged from various structural BMPs. For example, evidence from his study suggests that even under the best design and maintenance conditions, the total phosphorus concentration of water discharged from current stormwater BMPs (including stormwater BMP trains) is approximately 0.10 to 0.15 mg/l. These concentrations exceed the threshold concentration for the onset of nuisance algae blooms described in the water quality section of this document. While there is some dilution when the stormwater discharge enters the stream reducing the total phosphorus concentration, over time continual discharge at this rate could accelerate the eutrophication of the waterbodies within the Little Blue River Watershed.

Source reduction of pollutants includes strong erosion control efforts during construction activities. Sediment release from active construction sites can be several orders of magnitude greater than release from fully developed sites. The potential for release is even greater on highly erodible or potentially highly soils. Shelbyville has and erosion control ordinance in place, but this ordinances must be enforced. The new National Pollutant Discharge Elimination System (NPDES) Phase II regulations will assist local erosion control agencies in strengthening erosion control efforts. Communities can also help by ensuring local erosion control agencies have sufficient funding to hire the staff needed to perform inspections and adequate regulatory power to enforce existing rules.

Site-Specific Design

A corollary to source and conveyance reduction of stormwater pollutants is requiring any new development to consider existing natural features of the property in its site design. For example, should developers build on the open lots along State Road 44 and Interstate 74, buildings should be clustered as far away from the Little Blue River flowing through those parcels, preserving a buffer zone around the stream. Similarly, any residential subdivision development proposed in the areas of the watershed where soils are generally more permeable should utilize grassed shoulders and roadside infiltration swales rather than curb and gutter systems, which are present in some of the newer residential subdivisions around the Shelbyville. Additionally, ordinances should allow flexibility in determining appropriate BMPs on a case-by-case basis. Ordinances should also create incentives for developers to reduce stormwater runoff at its source and to choose BMP options with high removal efficiencies for phosphorus, one of the primary contaminant of concern in the Little Blue River Watershed.

Planning and Ordinances/Voluntary Agreements

Because water quality in streams often reflects the land use and land management in the watershed, good land management is necessary to ensure the ecological health of any stream. Planning is one component of good land management.

While watershed stakeholders can do all they can to support established policies and ordinances, authorized jurisdictions must enforce existing ordinances in order for the ordinances to protect the streams' ecological health. One area in particular that could use more attention is the enforcement of existing erosion control ordinances. The city and county both have some form of an erosion control ordinance covering many types of projects including but not limited to individual construction projects, subdivision construction, and roadway construction. Unfortunately, poor erosion control management was observed on several active construction sites during watershed inspections. The most commonly observed problem was a lack of trenching of silt fence. In order to properly control sediment loss, silt fences must be trenched into the ground. Without trenching, silt and sediment will easily escape from the site during a storm event. The presence of an erosion control ordinance is not sufficient to prevent this from occurring. A well-funded, active enforcement program must accompany any erosion control ordinance to ensure the protection of the Little Blue River and its tributaries.

Watershed stakeholders might also consider voluntary agreements where enforceable ordinances are not possible. An example of such an agreement would be an agreement to prohibit the use of fertilizers that contain phosphorus in urban areas adjacent to the Little Blue River, such as Arlington and Shelbyville. Several northern Indiana lake associations have voluntary agreements like this. To help association members abide by the agreement, some lake associations have purchased large quantities of phosphorus free fertilizer to distribute to their members. Other associations have provided members with information on lawn/landscape care contractors who only use phosphorus free, slow release fertilizers. A similar voluntary agreement on the use of phosphorus free fertilizers within urban areas is possible among Little Blue River Watershed stakeholders with the Shelby or Rush County SWCDs providing access to phosphorus free fertilizer. While there is no consequence for those who ignore the agreement, the stream would still benefit from the actions of those who do abide by the agreement. Voluntary agreements such as this and any others deemed important by watershed stakeholders should not be ignored simply because there are unenforceable.

Individual Property Owners Best Management Practices

Individual property owners can take several actions to improve the Little Blue River and its tributaries. First, watershed property owners within residential and areas should reduce or eliminate the use of fertilizers and pesticides. These lawn and landscape-care products are a source of nutrients and toxins to the stream. Landowners typically apply more fertilizer to lawns and landscaped areas than necessary to achieve the desired results. Plants can only utilize a given amount of nutrients. Nutrients not absorbed by the plants or soil will run into the stream either directly for those residents along the streambank or indirectly via storm drains. This simply fertilizes the rooted plants and algae in the stream. At the very minimum, landowners should follow dosing recommendations on product labels and avoid fertilizer/pesticide use within 10 feet of hard surfaces such as roads, driveways, and sidewalks. Where possible, natural landscapes should be maintained to eliminate the need for pesticides and fertilizers. Alternatively, landowners should consider replacing high maintenance turf grasses with grasses that have lower maintenance requirements such as some fescue (*Festuca*) species.

If a landowner considers fertilizer use necessary, the landowner should apply phosphorus-free fertilizers. Most fertilizers contain both nitrogen and phosphorus. However, the soil usually contains enough natural phosphorus to allow for plant growth. As a consequence, fertilizers with only nitrogen work as well as those with both nutrients. The excess phosphorus that cannot be absorbed by the grass or plants runs off into the stream, again either directly or via storm drains. Landowners can have their soil tested to ensure that their property does indeed have sufficient phosphorus and no additional phosphorus needs to be added. The local Soil and Water Conservation District or the NRCS can usually provide information on soil testing.

Riparian landowners should also avoid depositing lawn waste such as leaves and grass clippings in the stream as this adds to the nutrient base in the streams. Pet and other animal waste that enters the stream also contribute nutrients and pathogens to the stream. All of these substances require oxygen to decompose. Yard, pet, and animal waste should be placed in residents' solid waste containers to be taken to the landfill rather than leaving the waste on the lawn to decompose.

Each riparian property owner should investigate local drains, roads, parking areas, driveways, and rooftops. Resident surveys conducted on northern Indiana lakes have indicated that many lakeside houses have local drains of some sort on their properties. It is likely that riparian property owners have established similar water control methods. These drains contribute to sediment and nutrient loading and thermal pollution to the stream. Where possible, alternatives such as French drains (gravel filled trenches), wetland filters, catch basins, and native plant overland swales should be considered instead of piping the water directly to the stream.

Residents should disconnect stormwater drainage paths and consider the installation of vegetative filters, rain gardens, gravel infiltration trenches, or other drainage structures that promote infiltration and pollutant treatment over stormwater conveyance. While connecting downspouts with street drains keeps lawns well drained, these direct drainages prevent any pollutant treatment or infiltration (and therefore loss of stormwater volume) that the lawn or natural landscape may provide. Disconnecting these individual stormwater conduits should especially be encouraged in the areas of the watershed where soils are best suited for this.

Lastly, individuals should take steps to prevent unnecessary pollutant release from their property. With regard to car maintenance, property owners should clean any automotive fluid (oil, antifreeze, etc.) spills immediately. Driveways and street fronts should be kept clean and free of sediment. Regular hardscape cleaning would help reduce sediment and sediment-attached nutrient loading to the streams in the watershed. Street cleaning would also reduce the watershed loading of heavy metals and other toxicants associated with automobile use. Residents should avoid sweeping driveway silt and debris into storm drains. Rather, any sediment or debris collected during cleaning should be deposited in a solid waste container.

9.0 FUTURE WORK

Although the current study did not directly identify obstacles or special challenges for watershed-level projects in the Little Blue River Watershed, data collected during a phone survey of hundreds of producers in the 21 Rural Clean Water Program (RCWP) project areas provides some information with respect to the most typical obstacle encountered in watershed projects: private landowner willingness to participate. The purpose of the survey was to evaluate difference between farmers who chose to participate in the RCWP projects and those who did not (Gale et al., 1993). Participation was positively correlated with the following factors: total acreage farmed, farm sales, property/equipment values, water pollution awareness, access to water quality/conservation materials and information, education level, willingness to take risks, availability of financial (cost-share) incentives, and level/frequency of one-to-one contact between project personnel and farmers (Osmond and Gale, 1995). (An example of a positive correlation would be that more producers participated if more cost-share incentives were available.) The study found that producers who were tenant farmers or were employed off-farm were less likely to participate in conservation programs. The main reason landowners did not participate was that they did not believe water quality to be a problem.

The Shelby and Rush County SWCDs can take action to overcome this obstacle of private landowner willingness to participate in recommended projects by providing landowners with information about water quality and the various programs (like LARE) that are available to cost-share best management initiatives. The SWCD may be able to use a LARE watershed land treatment project as a “showcase” project to build stakeholder interest and participation. The District could also encourage a local high school science class to initiate volunteer monitoring in the watershed in order to raise awareness and provide education for children.

9.1 FUNDING SOURCES

There are several cost-share grants available from both state and federal government agencies specific to watershed management. Community groups and/or Soil and Water Conservation Districts can apply for the majority of these grants. The main goal of these grants and other funding sources is to improve water quality though the use of specific BMPs. As public awareness shifts towards watershed management, these grants will become more and more competitive. Therefore, any association interested in improving water quality through the use of grants must become active soon. Once an association is recognized as a "watershed management activist" it will become easier to obtain these funds repeatedly. The following are some of the possible major funding sources available to lake and watershed associations for watershed management.

Lake and River Enhancement Program (LARE)
LARE is administered by the Indiana Department of Natural Resources, Division of Soil Conservation. The program's main goals are to control sediment and nutrient inputs to lakes and streams and prevent or reverse degradation from these inputs through the implementation of corrective measures. Under present policy, the LARE program may fund lake and watershed specific construction actions up to $100,000 for a single project or $300,000 for all projects on a lake or stream. Cost-share approved projects require a 0-25% cash or in-kind match, depending on the project. LARE also has a "watershed land treatment" component that can provide grants to SWCDs for multi-year projects. The funds are available on a cost-sharing basis with farmers who implement various BMPs. Both the LARE programs are recommended as a project funding source for the Little Blue River Watershed. More information about the LARE program can be found at http://www.in.gov/dnr/soilcons/programs/lare.

Clean Water Act Section 319 Nonpoint Source Pollution Management Grant
The 319 Grant Program is administered by the Indiana Department of Environmental Management (IDEM), Office of Water Management, Watershed Management Section. 319 is a federal grant made available by the Environmental Protection Agency (EPA). 319 grants fund projects that target nonpoint source water pollution. Nonpoint source pollution (NPS) refers to pollution originating from general sources rather than specific discharge points (Olem and Flock, 1990). Sediment, animal and human waste, nutrients, pesticides, and other chemicals resulting from land use activities such as mining, farming, logging, construction, and septic fields are considered NPS pollution. According to the EPA, NPS pollution is the number one contributor to water pollution in the United States. To qualify for funding, the water body must meet specific criteria such as being listed in the state's 305(b) report as a high priority water body or be identified by a diagnostic study as being impacted by NPS pollution. Funds can be requested for up to $300,000 for individual projects. There is a 25% cash or in-kind match requirement. To qualify for implementation projects, there must be a watershed management plan for the receiving waterbody. This plan must meet all of the current 319 requirements. This diagnostic study serves as an n excellent foundation for developing a watershed management plan since it satisfies several, but not all, of the 319 requirements for a watershed management plan. More information about the Section 319 program can be obtained from http://www.in.gov/idem/water/planbr/wsm/319main.html.

Section 104(b)(3) NPDES Related State Program Grants
Section 104(b)(3) of the Clean Water Act gives authority to a grant program called the National Pollutant Discharge Elimination System (NPDES) Related State Program Grants. These grants provide money for developing, implementing, and demonstrating new concepts or requirements that will improve the effectiveness of the NPDES permit program that regulates point source

discharges of water pollution. Projects that qualify for Section 104(b)(3) grants involve water pollution sources and activities regulated by the NPDES program. The awarded amount can vary by project and there is a required 5% match. For more information on Section 104(b)(3) grants, please see the IDEM website at: http://www.in.gov/idem/water/planbr/wsm/104main.html.

Section 205(j) Water Quality Management Planning Grants
Funds allocated by Section 205(j) of the Clean Water Act are granted for water quality management planning and design. Grants are given to municipal governments, county governments, regional planning commissions, and other public organizations for researching point and non-point source pollution problems and developing plans to deal with the problems. According to the IDEM Office of Water Quality website: "The Section 205(j) program provides for projects that gather and map information on non-point and point source water pollution, develop recommendations for increasing the involvement of environmental and civic organizations in watershed planning and implementation activities, and implement watershed management plans. No match is required. For more information on and 205(j) grants, please see the IDEM website at: http://www.in.gov/idem/water/planbr/wsm/205jmain.html.

Other Federal Grant Programs
The USDA and EPA award research and project initiation grants through the U.S. National Research Initiative Competitive Grants Program and the Agriculture in Concert with the Environment Program.

Watershed Protection and Flood Prevention Program
The Watershed Protection and Flood Prevention Program is funded by the U.S. Department of Agriculture and is administered by the Natural Resources Conservation Service. Funding targets a variety of watershed activities including watershed protection, flood prevention, erosion and sediment control, water supply, water quality, fish and wildlife habitat enhancement, wetlands creation and restoration, and public recreation in small watersheds (250,000 or fewer acres). The program covers 100% of flood prevention construction costs or 50% of construction costs for agricultural water management, recreational, or fish and wildlife projects.

Conservation Reserve Program
As already discussed, the Conservation Reserve Program (CRP) is funded by the USDA and administered by the Farm Service Agency (FSA). CRP is a voluntary, competitive program designed to encourage farmers to establish vegetation on their property in an effort to decrease erosion, improve water quality, or enhance wildlife habitat. The program targets farmed areas that have a high potential for degrading water quality under traditional agricultural practices or areas that might make good wildlife habitat if they were not farmed. Such areas include highly erodible land, riparian zones, and farmed wetlands. Currently, the program offers continuous sign-up for practices like grassed waterways and filter strips. Participants in the program receive cost share assistance for any plantings or construction as well as annual payments for any land set aside.

Wetlands Reserve Program

The Wetlands Reserve Program (WRP) is funded by the USDA and is administered by the NRCS. WRP is a subsection of the Conservation Reserve Program. This voluntary program provides funding for the restoration of wetlands on agricultural land. To qualify for the program, land must be restorable and suitable for wildlife benefits. This includes farmed wetlands, prior converted cropland, farmed wet pasture, farmland that has become a wetland as a result of flooding, riparian areas which link protected wetlands, and the land adjacent to protected wetlands that contribute to wetland functions and values. Landowners may place permanent or 30-year easements on land in the program. Landowners receive payment for these easement agreements. Restoration cost-share funds are also available. No match is required.

Grassland Reserve Program

The Grassland Reserve Program (GRP) is funded by the USDA and is administered by the NRCS. GRP is a voluntary program that provides funding the restoration or improvement of natural grasslands, rangelands, prairies or pastures. To qualify for the program the land must consist of at least a 40 acre contiguous tract of land, be restorable, and provide water quality or wildlife benefit. Landowners may enroll land in the Grassland Reserve Program for 10, 15, 20, or 30 years or enter their land into a 30-year permanent easement. Landowners receive payment of up to 75% of the annual grazing value. Restoration cost-share funds of up to 75% for restored or 90% for virgin grasslands are also available.

Community Forestry Grant Program

The U.S. Forest Service through the Indiana Department of Natural Resources Division of Forestry provides three forms of funding for communities under the Community Forestry Grant Program. Urban Forest Conservation Grants (UFCG) are designed to help communities develop long term programs to manage their urban forests. UFCG funds are provided to communities to improve and protect trees and other natural resources; projects that target program development, planning, and education are emphasized. Local municipalities, not-for-profit organizations, and state agencies can apply for $2,000-20,000 annually. The second type of Community Forestry Grant Program, the Arbor Day Grant Program, funds activities which promote Arbor Day efforts and the planting and care of urban trees. $500-1000 grants are generally awarded. The Tree Steward Program is an educational training program that involves six training sessions of three hours each. The program can be offered in any county in Indiana and covers a variety of tree care and planting topics. Generally, $500-1000 is available to assist communities in starting a county or regional Tree Steward Program. Each of these grants requires an equal match.

Forest Land Enhancement Program (FLEP)

FLEP replaces the former Forestry Incentive Program. It provides financial, technical, and educational assistance to the Indiana Department of Natural Resources Division of Forestry to assist private landowners in forestry management. Projects are designed to enhance timber production, fish and wildlife habitat, soil and water quality, wetland and recreational resources, and aesthetic value. FLEP projects include implementation of practices to protect and restore forest lands, control invasive species, and preserve aesthetic quality. Projects may also include reforestation, afforestation, or agroforestry practices. The IDNR Division of Forestry has not determined how they will implement this program; however, their website indicates that they are working to determine their implementation and funding procedures. More information can be found at http://www.in.gov/dnr/forestry.

Wildlife Habitat Incentive Program

The Wildlife Incentive Program (WHIP) is funded by the USDA and administered by the NRCS. This program provides support to landowners to develop and improve wildlife habitat on private lands. Support includes technical assistance as well cost sharing payments. Those lands already enrolled in WRP are not eligible for WHIP. The match is 25%.

Environmental Quality Incentives Program

The Environmental Quality Incentives Program (EQIP) is a voluntary program designed to provide assistance to producers to establish conservation practices in target areas where significant natural resource concerns exist. Eligible land includes cropland, rangeland, pasture, and forestland, and preference is given to applications which propose BMP installation that benefits wildlife. EQIP offers cost-share and technical assistance on tracts that are not eligible for continuous CRP enrollment. Certain BMPs receive up to 75% cost-share. In return, the producer agrees to withhold the land from production for five years. Practices that typically benefit wildlife include: grassed waterways, grass filter strips, conservation cover, tree planting, pasture and hay planting, and field borders. Best fertilizer and pesticide management practices, innovative approaches to enhance environmental investments like carbon sequestration or market-based credit trading, and groundwater and surface water conservation are also eligible for EQIP cost-share.

Small Watershed Rehabilitation Program

The Small Watershed Rehabilitation Program provides funding for rehabilitation of aging small watershed impoundments that have been constructed within the last 50 years. This program is newly funded through the 2002 Farm Bill and is currently under development. More information regarding this and other Farm Bill programs can be found at http://www.usda.gov/farmbill.

Farmland Protection Program

The Farmland Protection Program (FPP) provides funds to help purchase development rights in order to keep productive farmland in use. The goals of FPP are: to protect valuable, prime farmland from unruly urbanization and development; to preserve farmland for future generations; to support a way of life for rural communities; and to protect farmland for long-term food security.

Debt for Nature

Debt for Nature is a voluntary program that allows certain FSA borrowers to enter into 10-year, 30-year, or 50-year contracts to cancel a portion of their FSA debts in exchange for devoting eligible acreage to conservation, recreation, or wildlife practices. Eligible acreage includes: wetlands, highly erodible lands, streams and their riparian areas, endangered species or significant wildlife habitat, land in 100-year floodplains, areas of high water quality or scenic value, aquifer recharge zones, areas containing soil not suited for cultivation, and areas adjacent to or within administered conservation areas.

Partners for Fish and Wildlife Program

The Partners for Fish and Wildlife Program (PFWP) is funded and administered by the U.S. Department of the Interior through the U.S. Fish and Wildlife Service. The program provides technical and financial assistance to landowners interested in improving native habitat for fish and wildlife on their land. The program focuses on restoring wetlands, native grasslands, streams, riparian areas, and other habitats to natural conditions. The program requires a 10-year cooperative agreement and a 1:1 match.

North American Wetland Conservation Act Grant Program

The North American Wetland Conservation Act Grant Program (NAWCA) is funded and administered by the U.S. Department of Interior. This program provides support for projects that involve long-term conservation of wetland ecosystems and their inhabitants including waterfowl, migratory birds, fish, and other wildlife. The match for this program is on a 1:1 basis.

National Fish and Wildlife Foundation (NFWF)

The National Fish and Wildlife Foundation is administered by the U.S. Department of the Interior. The program promotes healthy fish and wildlife populations and supports efforts to invest in conservation and sustainable use of natural resources. The NFWF targets six priority areas which are wetland conservation, conservation education, fisheries, neotropical migratory bird conservation, conservation policy, and wildlife and habitat. The program requires a minimum of a 1:1 match. More information can be found at http://www.nfwf.org/about.htm.

Bring Back the Natives Grant Program

Bring Back the Natives Grant Program (BBNG) is a NFWF program that provides funds to restore damaged or degraded riverine habitats and the associated native aquatic species. Generally, BBNP supports on the ground habitat restoration projects that benefit native aquatic species within their historic range. Funding is jointly provided by a variety of federal organizations including the U.S. Fish and Wildlife Service, Bureau of Land Management, and U.S. Department of Agriculture and the National Fish and Wildlife Foundation. Typical projects include those that revise land management practices to remove the cause of habitat degradation, provide multiple specie benefit, include multiple project partners, and are innovative solutions that assist in the development of new technology. A 1:1 match is required; however, a 2:1 match is preferred. More information can be obtained from http://www.nfwf.org.

Native Plant Conservation Initiative

The Native Plant Conservation Initiative (NPCI) supplies funding for projects that protect, enhance, or restore native plant communities on public or private land. This NFWF program typically funds projects that protect and restore of natural resources, inform and educate the surrounding community, and assess current resources. The program provides nearly $450,000 in funding opportunities annually awarding grants ranging from $10,000-50,000 each. A 1:1 match is required for this grant. More information can be found at http://www.nfwf.org/programs/grant_apply.htm.

Freshwater Mussel Fund

The National Fish and Wildlife Foundation and the U.S. Fish and Wildlife Service fund the Freshwater Mussel Fund which provides funds to protect and enhance freshwater mussel resources. The program provides $100,000 in funding to approximately 5-10 applicants annually. More information can be found at http://www.nfwf.org/programs/grant_apply.htm.

Non-Profit Conservation Advocacy Group Grants
Various non-profit conservation advocacy groups provide funding for projects and land purchases that involve resource conservation. Ducks Unlimited and Pheasants Forever are two such organizations that dedicate millions of dollars per year to projects that promote and/or create wildlife habitat.

U.S. Environmental Protection Agency Environmental Education Program
The USEPA Environmental Education Program provides funding for state agencies, non-profit groups, schools, and universities to support environmental education programs and projects. The program grants nearly $200,000 for projects throughout Illinois, Indiana, Michigan, Minnesota, Wisconsin, and Ohio. More information is available at http://www.epa.gov/region5/ened/grants.html.

Indianapolis Power and Light Company (IPALCO) Golden Eagle Environmental Grant
The IPALCO Golden Eagle Grant awards grants of up to $10,000 to projects that seek improve, preserve, and protect the environment and natural resources in the state of Indiana. The award is granted to approximately 10 environmental education or restoration projects each year. Deadline for funding is typically in January. More information is available at http://www.ipalco.com/ABOUTIPALCO/Environment/Golden_Eagle.html

Nina Mason Pulliam Charitable Trust (NMPCT)
The NMPCT awards various dollar amounts to projects that help people in need, protect the environment, and enrich community life. Prioritization is given to projects in the greater Phoenix, AZ and Indianapolis, IN areas, with secondary priority being assigned to projects throughout Arizona and Indiana. The trust awarded nearly $20,000,000 in funds in the year 2000. More information is available at www.nmpct.org

9.2 WATERSHED RESOURCES
An important but often overlooked factor in accomplishing goals and completing projects in any watershed is resources within the watershed itself. These resources may be people giving of their time, local schools participating in projects, companies giving materials for project construction, or other donations. This study documents some of these available resources for the Little Blue River Watershed. It is important to note that this list is not all-inclusive, and some groups and donors may have been missed.

Coordinated Resource Management
The Coordinated Resource Management (CRM) process is an organized approach to the identification of local concerns, evaluation of natural resources, development of alternative actions, assistance from technical specialists, implementation of a selected alternative, evaluation of implementation activities, and involvement of all interested parties who wish to participate in watershed action. The goal of the CRM process is the development of an effective Watershed Management Plan. Further CRM information and its complementary Watershed Action Guide can be downloaded from the USDA/NRCS website at http://www.in.nrcs.gov. The CRM gives

guidance on how diverse groups of people can plan to maximize benefits to the greatest number of individuals while enhancing or maintaining the natural resource.

Hoosier Riverwatch

The Hoosier Riverwatch Program was started in 1994 by the State of Indiana to increase public awareness of water quality issues and concerns. Riverwatch is a volunteer stream monitoring program sponsored by the IDNR Division of Soil Conservation in cooperation with Purdue University Agronomy Department. Any citizen interested in water quality may volunteer to take a short training session held from May through October. Water monitoring equipment may be supplied to nonprofit organizations, schools, or government agencies by an equipment grant. Additionally, many SWCD offices (including the Shelby and Rush County SWCDs) have loaner equipment that can be borrowed. Several groups in the three counties actively participate in the Riverwatch Program. Table 71 contains information about groups that have conducted volunteer monitoring in the two counties. Because the Little Blue River has only been sporadically monitored through the Hoosier Riverwatch Program, more participation should be advocated within the study watershed especially since loaner equipment is readily available. More detailed information is available via the Hoosier Riverwatch web site at http://www.state.in.us/dnr/soilcons/riverwatch/.

Table 71. Groups that have participated in or received equipment from the Hoosier Riverwatch volunteer monitoring program in Rush and Shelby Counties.

County	Organization	City
Rush	Rush County SWCD	Rushville
Shelby	Morristown Community Schools	Morristown
Shelby	Coulston Elementary Schools	Shelbyville
Shelby	Shelby County SWCD	Shelbyville
Shelby	Ruth Lilly YMCA Outdoor Center	St. Paul

Source: Hoosier Riverwatch.

Volunteer Groups

Volunteer groups can be instrumental in planning projects, implementing projects, and monitoring projects once they are installed. Morristown Community Schools, Rush County SWCD, Shelby County SWCD, and Coulston Elementary School have all participated in the Hoosier Riverwatch program. Involving the people living in the watershed, especially school-age children, is a good way to promote natural resource awareness and a good way to get data collected and projects completed. Oftentimes, data collected by volunteer groups may be the only available data for a watershed. This data is very valuable in helping to establish baseline conditions with which to compare future conditions.

Purdue Agricultural Center Research and Demonstration Projects

The Purdue University Department of Agriculture operates eight agricultural centers throughout the state. Two of these, the Davis-Purdue Agricultural Center (DPAC) in Randolph County and the Southeast-Purdue Agricultural Center (SEPAC) in Jennings County, participate in on-going agricultural research that is relevant to challenges producers face in central and southern Indiana. DPAC consists of 460 acres of tillable land and 100 acres of managed forested land. Because of Dr. Burr Prentice's work in 1926 to number, map, and describe every tree greater than four inches in diameter on DPAC property the site is a registered natural landmark. Currently, research at DPAC focuses on soil fertility, crop diseases, weed control, insect problems, nutrient application rates, and forestry management (DPAC, 2003). Research at SEPAC occurs on 540 acres of corn, soybeans, and wheat and 160 acres of forestland and tree plantations. Soils at SEPAC are typical of southern Indiana having low organic matter content and high erosive potential. SEPAC research focuses on pest management, nutrient management, soil drainage, water quality, specialized botanical production, and forestry plantation management (SEPAC, 2003). Although these stations are not in or directly adjacent to the Little Blue River Watershed research conducted at either DPAC or SEPAC may provide insight on future management techniques that could be applicable to the Little Blue River Watershed area.

10.0 RECOMMENDATIONS

All of the subwatersheds within the Little Blue River Watershed could benefit from land treatment and best management strategies as already described in detail in the Watershed Study and Management Sections. Finances, time, manpower, and other restraints make it impossible to implement all of these management techniques at once. Thus, it is necessary to prioritize the recommendations.

The prioritizations and recommendations listed below are simply guidelines based on conditions documented during this study. These conditions may change as land use within the watershed changes. Management efforts may need to be prioritized differently based on project feasibility and individual landowner willingness to participate. To ensure maximum participation in any management effort, all watershed stakeholders should be allowed to participate in prioritizing the management efforts in the watershed.

It is also important to note that even if all stakeholders agree that this is the best prioritization to meet their needs, action need not be taken in this order. Some of the smaller, less expensive recommendations may be implemented while funds are raised to implement some of the larger projects. Many of the larger projects will require feasibility work to ensure landowner willingness to participate in the project. In some cases, it may be necessary to attain regulatory approval as well. Landowner endorsement and regulatory approval along with stakeholder input may ultimately determine the prioritization of management efforts.

Results from the mapping exercises, the aerial tour, the windshield survey, water quality sampling, biological sampling, habitat sampling, and the modeling exercise were used to prioritize tributary subwatersheds for future work. The tributary subwatersheds are discussed in order of priority. It is also important to note that in order to make prioritizations, it is necessary to make some generalizations. Additional general recommendations, like innovative riparian management system use and recommended practices for homeowners, follow the primary recommendations section. Many of these recommendations may already be in practice; however, for the sake of thoroughness, they are reiterated here.

10.1 TRIBUTARY SUBWATERSHED PRIORITIZATION

Based on the findings of this study, the order of prioritization for work, projects, and program enrollment within the Little Blue River Watershed tributary subwatersheds should be:

1. Little Gilson Creek (Site 9)
2. Rays Crossing Tributary (Site 2)
3. Cotton Run (Site 4)
4. Headwaters (Site 10)
5. Farmers Stream (Site 7)
6. Manilla Branch (Site 3)
7. Beaver Meadow Creek (Site 6)

Subwatershed priority is displayed in Figure 94.

The Little Gilson Creek Subwatershed (Site 9) is of top priority due to relatively high nitrate-nitrogen and *E. coli* concentrations, poor macroinvertebrate community structure, and a high phosphorus export rate based on land use. Little Gilson Creek contained the highest nitrate-nitrogen concentration of any of the stream sites during both base and storm flow. Additionally, *E. coli* concentrations exceeded the state standard at this site during storm flow. Little Gilson Creek possessed the lowest mIBI (2.5) and QHEI (30) scores indicating that the stream was not capable of supporting its aquatic life use designation. The watershed possessed the highest phosphorus loss per unit area (1.88 kg P/ha-yr) as determined by the phosphorus model.

The Rays Crossing Tributary Subwatershed (Site 2) is also of high priority for possessing a high HEL:CRP ratio, high nitrate and pesticide leaching risk, and high nutrient and sediment loading rates per unit area relative to the other subwatersheds. The Rays Crossing Tributary Subwatershed possesses one of the highest HEL:CRP ratios (243:0); this means that for every acre of highly erodible land mapped in the subwatershed, zero acres of land is enrolled in the Conservation Reserve Program. The Rays Crossing Tributary Subwatershed contained a moderately high nitrate and pesticide leaching risk, as determined by Engel (Figures 18 and 19). The Rays Crossing Tributary Subwatershed loaded more ammonia-nitrogen, total Kjeldahl nitrogen, total phosphorus, and total suspended solids per unit area during storm flow and more ammonia-nitrogen and soluble reactive phosphorus per unit area during base flow to the Little Blue River than any other subwatershed. Additionally, Rays Crossing Tributary possessed the second highest total Kjeldahl nitrogen, total phosphorus, and total suspended solids loading rates per unit area during base flow. The site also exhibited relatively high nutrient and sediment concentrations during base and storm flow. This relatively poor water quality likely plays a role in impairing the site's biotic community.

The Cotton Run Subwatershed (Site 4) is also of high priority due to containing high nutrient and sediment loads per unit area, a relatively poor macroinvertebrate community, and a relatively high phosphorus export rate. The Cotton Run Subwatershed possessed higher total phosphorus and total suspended solids loading rate per unit area during base flow than any other subwatershed. The relatively poor macroinvertebrate community observed at this site reflects the poor water quality and poor habitat conditions in Cotton Run. Cotton Run also contained one of the highest normalized phosphorus loading rates (1.80 kg P/ha-yr) as determined by the phosphorus model.

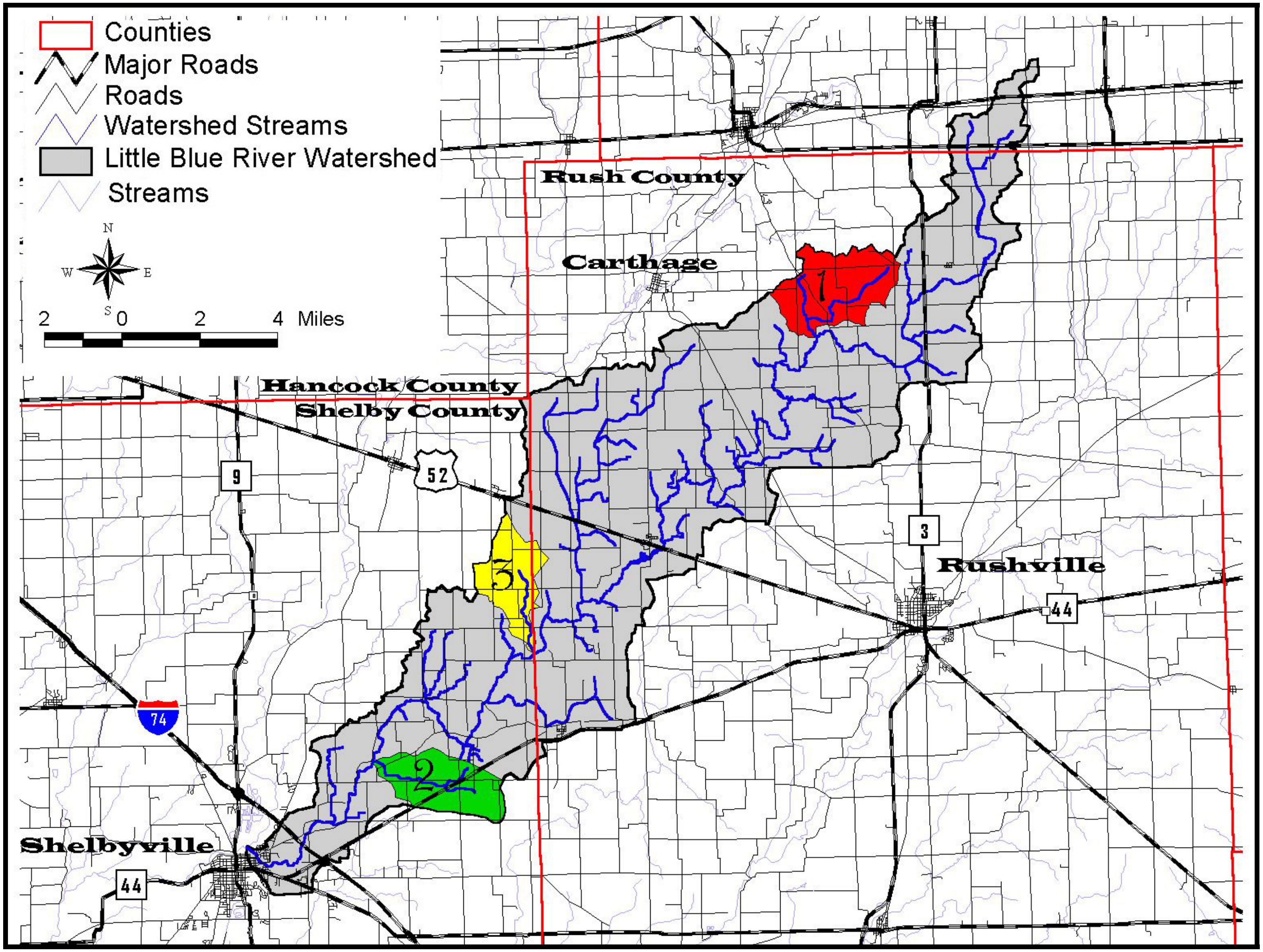


Figure 94. Subwatershed prioritization. Source: See Appendix A.

The remaining tributary subwatersheds, Manilla Branch (Site 3), Beaver Meadow Creek (Site 6), Farmers Stream (Site 7), and the Headwaters (Site 10), are of lower priority because they generally responsible for lower pollutant loading rates, possess more pollution intolerant macroinvertebrate communities and better water quality, and/or generally already contain more protected land in CRP than the tributary subwatersheds of top priority. Likewise, watershed areas draining through smaller tributaries not sampled during this study or directly to the Little Blue River should not be ignored during project targeting and implementation. Although the Little Gilson Creek Subwatershed is of the highest priority implementing water quality projects in any of the mainstem or tributary subwatersheds will improve water quality within the Little Blue River. Likewise, projects located in other portions of the watershed should not be ignored simply due to lower subwatershed prioritization. Implementing any water quality improvement project will increase water quality throughout the Little Blue River Watershed. As will be discussed in the Future Work Section, the primary obstacle facing watershed projects is typically landowner willingness to participate (Osmond and Gale, 1995). Management and participation certainly should be encouraged in the remaining four subwatersheds of lower overall priority.

10.2 PRIMARY RECOMMENDATIONS

Reduce nitrate-nitrogen concentrations in streams throughout the watershed. Nitrate-nitrogen concentrations were elevated at all watershed streams during both base and storm flow. Nitrate-nitrogen concentrations in the tributaries exceeded the Indiana state standard (10 mg/l) during storm flow (IAC, 2000). All concentrations exceeded the median level determined to support warmwater fauna in Ohio (Ohio EPA, 1999). Best management practice implementation to reduce nitrate-nitrogen loading to the streams, including wetland restoration, livestock fencing, septic system inspection and maintenance, and sewer installation, should be focused on Farmers Stream, Manilla Branch, Rays Crossing Tributary, and Little Gilson Creek Subwatersheds.

1. Reduce *E. coli* concentrations in streams throughout the watershed. *E. coli* concentrations exceeded the state standard at all sites during storm flow and at the Lower Little Blue River (Site 1), Manilla Branch (Site 3), Beaver Meadow Creek (Site 6), and Farmers Stream (Site 7) during base flow. Historic data documents high *E. coli* concentrations in Rays Crossing Tributary, Manilla Branch, and along the Little Blue River mainstem. The entire length of the Little Blue River is listed on the 303(d) list of impaired waterbodies for *E. coli*. The sources of *E. coli* in the Little Blue River Watershed have not been identified; however, wildlife, livestock and/or domestic animal defecations; manure fertilizers; previously contaminated sediments; and failing or improperly sited septic systems are common sources of the bacteria. Although a total maximum daily load (TMDL) will be developed for the Little Blue River, efforts should still be focused on reducing the amount of *E. coli* entering watershed streams from these and other sources. Because they exhibited relatively high *E. coli* concentrations during storm and/or base flow, best management practices such as livestock fencing, septic system inspection and maintenance, and sewer installation should be implemented in the Rays Crossing Tributary, Manilla Branch, and Beaver Meadow Creek Subwatersheds. Sources of *E. coli* near and immediately upstream of the Lower Little Blue River sampling site (Site 1) should also be inspected to try to determine the reason for the high *E. coli* concentration during storm flow.

2. Reduce nitrate-nitrogen concentrations in streams throughout the watershed. Nitrate-nitrogen concentrations were elevated at all watershed streams during both base an storm flow. Nitrate-nitrogen concentrations in the tributaries exceeded the Indiana state standard (10 mg/l) during storm flow (IAC, 2000). All concentrations exceeded the median level determined to support warmwater fauna in Ohio (Ohio EPA, 1999). Best management practice implementation to reduce nitrate-nitrogen loading to the streams, including wetland restoration, livestock fencing, septic system inspection and maintenance, and sewer installation should be focused on in the Farmers Stream, Manilla Branch, Rays Crossing Tributary, and Little Gilson Creek Subwatersheds. Constructed wetlands that treat drainage prior to its release in streams should also be investigated in these subwatersheds. Constructed wetland are known for their ability to remove nitrate-nitrogen from waste streams. (See the Riparian Management System Model discussion in the Management Section of this report for more information on wetland restoration.)

3. Apply for Lake and River Enhancement (LARE) Watershed Land Treatment Funds to implement recommended BMPs and projects discussed for each subwatershed (Tables 43-52) based on subwatershed priority (Figure 94). Some of these projects include: livestock fencing, wetland restoration, filter strip installation, allowing natural riparian vegetation growth, bank stabilization, information and education efforts, buffer zone establishment, revegetation of exposed areas, and grassed waterway construction. This work should focus on interested landowners in identified critical areas first. Additional funding can be obtained from a variety of sources such as the Conservation Reserve Program, Wetland Reserve Program, and the Environmental Quality Incentives Program. These funds can be used separately or in conjunction with LARE Watershed Land Treatment funds. (The Funding Sources Section details these and other funding programs.)

4. Target best management practice implementation on non-protected parcels mapped as highly erodible land. Approximately 3.5% of the watershed (2,268 acres or 918.6 ha) is mapped as highly erodible land. However, only 61.4 acres (24.8 ha) of land is enrolled in the conservation program (Table 14). The Rays Crossing Tributary, Manilla Branch, and Beaver Meadow Creek Subwatersheds contained the largest HEL:CRP ratios. Efforts within these subwatersheds should focus on enrolling tracts of land mapped as highly erodible in the conservation reserve program. Land in the Headwaters Subwatershed should also be targeted for CRP implementation since it possessed the greatest total suspended solids loading rate per unit area of subwatershed.

5. Implement nutrient and pesticide management planning in areas of high nitrate and pesticide leaching risk. Much of the watershed has moderate to high risk of nitrate leaching (Figure 19). The northwest edge of Shelbyville is the largest area mapped as having high nitrate leaching risk. Much of this area is urban or residential, and therefore, not in production. Conversely, much of the Little Blue River Watershed is at low risk for pesticide leaching. However, there are three areas of concern: the mainstem of the Little Blue River from Arlington to Shelbyville, the Beaver Meadow Creek headwaters, and the Little Blue River headwaters east of State Road 3 (Figure 20). These areas should be targeted for nutrient and pesticide management planning.

10.3 GENERAL RECOMMENATIONS

1. Assist permitted point source operations like the confined feeding operations located throughout the watershed in implementing innovative waste management systems. Potential projects might include installing a wastewater treatment wetland at CFOs. A wastewater treatment wetland can reduce the high nitrogen concentration present in CFO wastewater. Constructing an innovative treatment for washwater such as redesigning washwater storage ponds to maximize utility, employing horizontal subsurface flow systems, or introducing vegetation for wetland treatment could reduce nutrient leaching to groundwater (O'Connor, 2002). Grant funding is available for projects of these types. (See the Funding Sources Section of this report for more specific information.)

2. Coordinate the projects referenced in primary recommendation #3 with the county drainage board to ensure that the project meets the goals of both the Soil and Water Conservation District (SWCD) and the drainage board. For example, a SWCD tree-planting project in an area that is scheduled for drainage project de-brushing will not result in the optimum use of resources. In fact, a landowner may be more willing to participate in a cost-share program following ditch maintenance projects. Although none of the ditches are currently "on the books" for dredging, landowners within the Little Blue River Watershed have petitioned the County Surveyor's office for assessment. Following assessment, much of Little Blue River or its tributaries could be slated for maintenance projects. If any maintenance projects occur on the Little Blue River or its tributaries implementation of conservation practices along these ditches and in their immediate watersheds is strongly encouraged to prevent the need for such maintenance projects in the future. It is recommended that the SWCD work closely with the drainage boards to ensure that conservation practices advocated in the Indiana Drainage Handbook (Burke, 1996) are followed when planning and implementing projects. These conservation practices recommend tree preservation, vegetative stabilization and seeding, stream environment enhancement, and tree replacement even near regulated drains. Additionally, the Indiana Lakes Management Work Group, an Indiana Legislature authorized and governor appointed group, also recommended that "drainage boards…implement all possible best management practices as indicated in the Indiana Drainage Handbook" (Case and Seng, 1999). The Group further suggested that the 1965 Indiana Drainage code (IC 36-9-27) be updated to "allow ditch maintenance assessments to be used to cost-share preventative measures such as streambank stabilization, riparian vegetation, and stable livestock access and stream crossings" and to "require drainage boards to develop a master plan (based on sound watershed management practices and with input from landowners) for each drain that proactively identifies sections of stream where landowners can restore protective riparian vegetation along stream sections that are never accessed for drain maintenance".

3. Extend management to the watershed level. Although streamside localized BMPs are important, research conducted in Wisconsin shows that the biotic community mostly responds to large-scale watershed influences rather than local riparian land use changes (Weigel et al., 2000). An example of working at the watershed-level is coordinating with producers to implement nutrient, pesticide, tillage, and coordinated resource management plans. It is important to note that the LARE Program will provide cost-share incentives for large-scale land practices like conservation tillage. Large-scale reductions in agricultural

non-point source pollutions are necessary for stream health improvement (Osmond and Gale, 1995).

4. Provide information about streams within the Little Blue River Watershed to local landowners. Landowners will be more likely to conserve and protect the creeks if they understand their value. The outreach program could include pointers on how landowners themselves can help protect the waterways.

5. Develop a watershed or land use management plan. A watershed management plan documents current conditions within a watershed, sets water quality goals for the watershed based on stakeholders' desires, outlines a plan of how to reach the goals, and provides for monitoring of success toward reaching the goals. To be effective, all stakeholders must be included in the plan's development. Because it documents the current watershed conditions, this report can serve as a starting point for the development of a watershed management plan.

6. Before initiating watershed treatment projects, consider conducting a survey of landowners in the watershed to determine landowners' concern for water quality problems, to evaluate landowners' opinions of management systems, and to quantify the value of surface and groundwater quality improvement. Use this information to work with interested landowners to formulate individual Resource Management Plans.

7. Reach out to a school or other volunteer group to set up volunteer monitoring at additional sites within the watershed through the Hoosier Riverwatch Program. This data will be a valuable resource by which to evaluate the success of projects implemented in the area.

8. Consider using innovative riparian management systems similar to the one discussed earlier in the Best Management Practice Section. Modified systems of this type would be especially beneficial for use in critical or vulnerable stream reaches where they could significantly impact non-point source pollution. Several critical stream reaches including Rays Crossing Tributary, Cotton Run, and Little Gilson Creek, were identified by this study.

9. Invite producers and other landowners to visit successful project sites. There is no better advertisement than a success story. Focus on information dissemination and transfer by scheduling on-site field days during non-busy seasons.

10. Work with a bulk seed distributor to make native plant seed available in large quantities at low prices.

11. Work with the Shelby, Rush, and Henry County Health Departments to ensure proper siting and engineering of septic systems. The use of alternative technology should be encouraged when conditions may compromise proper waste treatment. IDNR and USDA soil scientists in the area are a valuable resource for expertise in characterizing soils for septic use. Their knowledge could be tapped for future building and siting of systems. If building is necessary on a site where conditions are not suitable for a traditional system, alternative

technology could be constructed and the site used as a demonstration and education/outreach tool.

12. Homeowners in the watershed should:
    a. Avoid lawn fertilizing near the stream's edge.
    b. Examine all drains that lead from roads, driveways, or rooftops to the stream, and consider alternate routes for these drains that would filter pollutants before they reach the water.
    c. Keep organic debris like lawn clippings, leaves, and animal waste out of the water.
    d. Avoid mowing up to the stream's edge; Restore riparian habitat.
    e. Properly maintain on-site wastewater treatment systems. Systems should be pumped regularly and leach fields should be properly cared for. Undue pressure on systems may be alleviated by water conservation practices as well.
    f. Maintain field drainage tiles and use filter strips around tile risers.

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